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ADVENTURING IN SCIENCE

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SUMMER SCHOOL FOR TEACHERS

Exploring Our World

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ADVENTURING IN SCIENCE

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EXPLORING OUR WORLD

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OUR WORLD CHANGES

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USING OUR WORLD

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EXPLORING
OUR
WORLD

UNIT ONE

SCIENCE IN OUR LIVES

WE PREPARE FOR OUR EXPLORATIONS

In this book we shall explore our world with the help of modern science. But, first of all, exactly what *is* science?

◆

How many times have we heard about the marvelous discoveries of modern scientists?

But how, exactly, does a scientist differ from anyone else?

What tools does a scientist use and how does he use them?

◆

How many times have we heard it said that we live in an age of science?

But how, exactly, does an age of science differ from any other age?

What, in short, has science done to us and to the world around us?

◆

Unit One of this book will help us find the answers to these questions.

When we have found the answers we shall be ready to start exploring our world.

CHAPTER ONE

What Is Science?

WHAT SCIENTISTS ARE LIKE

The Scientist and the Wizard. Last night one of the authors of this book saw a movie. It was about a man who could perform magic. The man had the kind of eyes that seem to look right through you. He performed his magic in a dark and creepy sort of room, full of oddly shaped glass tubes and bottles. The tubes and bottles were full of ugly-looking liquids, which frothed furiously when stirred or heated. The man worked mysteriously in the strange room. He was supposed to be a scientist in the midst of a marvelous discovery.

He reminded one of the wizard in the fairy tale who made a brew that could change a human being into an animal. Indeed, the scientist of the movie is only the wizard of the fairy tale in modern dress. Both are magicians with terrible, unusual, and unnatural powers. Fortunately both are purely imaginary. The modern scientist is not a fearful person. The modern scientific laboratory is not a fearful place. The only wizards—and the only scientists who resemble wizards—are in storybooks and movies.

The True Scientist. The best way to discover that scientists are not wizards and that science is not magic is to watch a real scientist at work. Let us imagine ourselves in an automobile driving westward across the southern part of New Mexico. It is a very hot day in mid-July. We wish that we were up in the cool-looking mountains which stand against the western sky rather than on the dry and treeless desert at their feet.

We have seen many interesting things along our way. When we reach the middle of the state, we see an unbelievable thing. For there beyond the little village of Alamogordo, and right on the hot desert floor, is a mighty field of snow!

We draw nearer, and the snow field seems to grow larger. We can plainly see the huge drifts billowing off to the mountains miles away. We ask a man on the village street if we can believe our eyes. He wipes the perspiration from his face and tells us a little sadly that what we see is not snow but sand—the whitest sand in the world. He also tells us that some scientists are camped at the edge of the sand hills and that they might tell us more about them.

It is not difficult to persuade our parents to drive to the edge of the weird white world. They are almost as excited as we are! As the sand hills rise higher with our approach, we catch sight of the little brown tent of the scientists. Driving up, we are greeted by a young man with a friendly smile. We ask him where we can find the scientists, and are surprised when he says that he is one of them. We had not known that a scientist could be so young and friendly.

We ask him to tell us about the white sand, but in our excitement we pepper him with so many questions that he has no chance to answer them. What is the sand made of? Why is it so different from the brown sand we have seen on the beach? How did it get here? Do any plants or animals live on it and, if so, how do they live and what do they look like?

"It would take me a long time to answer all those questions," he replies, "even if I knew all the answers. But I don't know all the answers—at any rate, not yet. That is why my friends and I are here—to try to find the answers. The others are out in the hills now, hunting answers."

Seeing our disappointment, he goes on: "Of course we have already learned something, and every day we are learning a little more. We know that this sand is made of almost pure gypsum, a mineral that forms in salty water which is drying up in the sun. We know that this part of New Mexico was once under the sea because we find the shells of sea animals in those rocks over there.

"The rocks were laid down as layers of sand and mud in an arm of some ancient sea. They later hardened into rock. The gypsum was laid down with the sand and mud. When the sea dried up, the wind and rain broke up the gypsum and heaped the broken pieces in these white hills."

The strange white sands of Alamogordo look like drifted snow

Desert Magazine

"But why is the gypsum so clean?" we ask. "Why wasn't it mixed up with pieces of the hardened mud? Why was there so much more gypsum here than anywhere else? Why did the ancient sea dry up?"

"Ah," he answers, "you are now asking the same questions that we are asking. We aren't satisfied that we have found the right answers yet.

"But come into the tent," he continues, "and I'll show you something interesting."

There in a cage are several little mice—as white as snow!

"These little creatures," the scientist tells us, "live in burrows in the sand. There are no other mice like them anywhere else in New Mexico. They seem to be white because they live in a white world—like polar bears on the ice floes in the Arctic. We are trying to find out how they are related to the gray mice that live on the desert over there, less than a mile away, and how they got their strange white fur. We haven't found out yet, but we are hoping."

One question leads to another as our friendly guide takes us for a walk over the beautiful white hills and to the rocks, where we dig up some of the sea shells that were buried there so long ago. We like the scientist very much. He is not at all like the scientist in the movie with the mysterious manner and the frightening eye. He is just a person like ourselves, curious to know about the interesting things in the world.

Before leaving we tell him that we wish we could be scientists too, doing all the interesting things that he is doing. "But you *can* be scientists," he answers. "Anyone who finds a problem that interests him and tries to solve it is being a scientist. You don't have to come to the White Sands of Alamogordo to be a scientist. You don't have to

We examine the shells that were preserved in the hardened mud of an ancient sea

work in a laboratory full of costly instruments. You can be a scientist in your own home if only you are curious about how and why things are as they are."

HOW SCIENTISTS ARE MADE

Curiosity the Beginning of Science. The scientist in the New Mexico desert is right. Curiosity about the world in which we live is the soil in which science grows. Have you ever asked yourself why it is that human beings are the only creatures that can know enough about the world to change it? Why are other creatures content to take the world as they find it? Why are men alone forever seeking to change it?

Perhaps there are some rabbits living in the woods beyond your town. They eat the tender young shoots of the plants that grow in the woods. When they get tired they sleep under bushes or in hollow trees. Think of the men

These two are neighbors, but see how differently they live

and women who live in the town. They and the rabbits are neighbors. Both live in the same world. Yet how different are the lives of the men and women from the lives of the rabbits!

The men and women are not content to eat only the plants that grow wild around their home. They raise grains and vegetables and fruits which they like better and which are better for them. Nor are they content to sleep in or under the trees. They cut up the trees into lumber. They build houses with the lumber which shield them from the wind, the rain, the heat, and the cold.

Discontent with the hardships of the natural world is not enough to enable a creature to make its life easier and better. When the rabbit trembles in his burrow at the barking of a dog, he is probably as discontented with his lot as any human being ever was. But he cannot change it, because he doesn't know how.

The first step in knowing how to change the world is to be curious about it. "Why are things as they are?" must be asked before "How can we change things to make them better suit our needs?" Man is curious about the world.

He wants to know what everything is and how everything works. That is why he has been able to make the discoveries and inventions which have set him apart from all other living creatures.

How many times have you asked the questions "What is that?" "How does it work?" "Why?" Every time you ask those questions you are being a true human being. You are also being a true scientist. *What? How?* and *Why?* are the foundations on which all science rests.

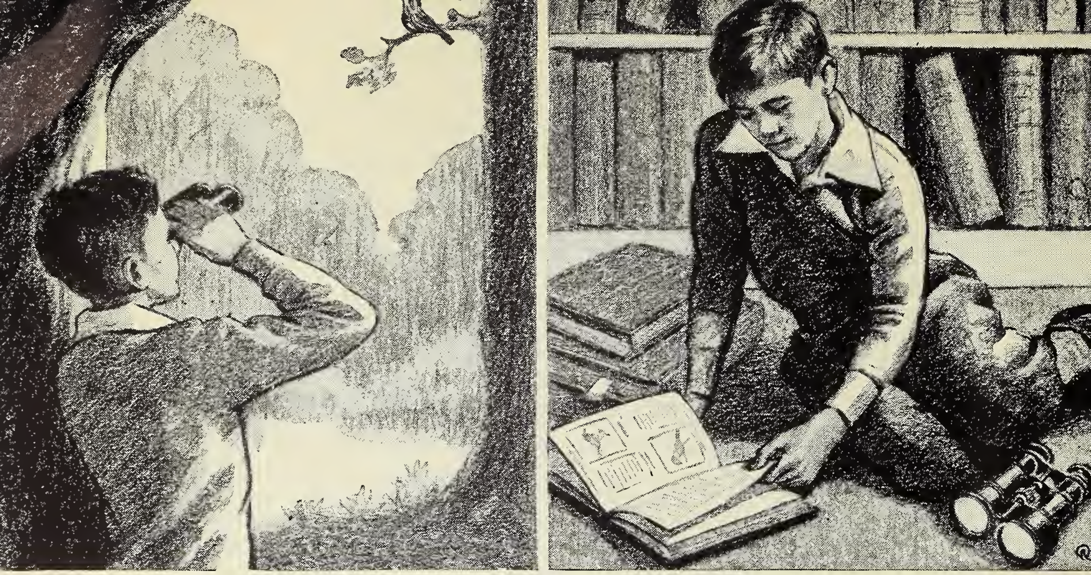
The Problem of Finding Problems. The scientist at the white sands said that anyone who tries to solve a problem is a scientist. But where can we find problems to solve? Have the scientists solved so many of the problems that there are few left for us to work on?

You know that the answer is No. Every time you ask What? How? or Why? you have found a problem. It may not be a problem for someone older than yourself who has already found and solved it. But it is a problem for you. It is just as much a problem as that of the white mice of Alamogordo. In solving it you may prove yourself to be just as much a scientist as the person who solves a problem which nobody has ever solved before.

Problems are all around us. We meet them every day. *What* is that bird that sings all day in the orchard? *How* do heavy airplanes stay up in the air? *Why* does frost make Christmas trees on the windowpanes? The problem of finding problems is no problem at all!

THE TOOLS OF SCIENCE

Observation. After a problem is found, observation is generally the first step necessary to solve it in a scientific manner. Take the problem of the bird in the orchard. Our



Identifying birds is a fine way of improving our power of observation

first impression of it was not very definite,—a streaky brown bird like a sparrow. We look through a bird book and find pictures of many streaky brown birds, all of them sparrows. Our observations were not exact enough to enable us to identify the bird in the orchard.

We return for more observations. We find the bird warbling its happy song from the branch of a tree. We look at it sharply and try to discover some mark that might distinguish it from other streaky brown birds. Presently we notice in the middle of the breast a heavy splotch of brown which is clearly set off from the other brown markings by white.

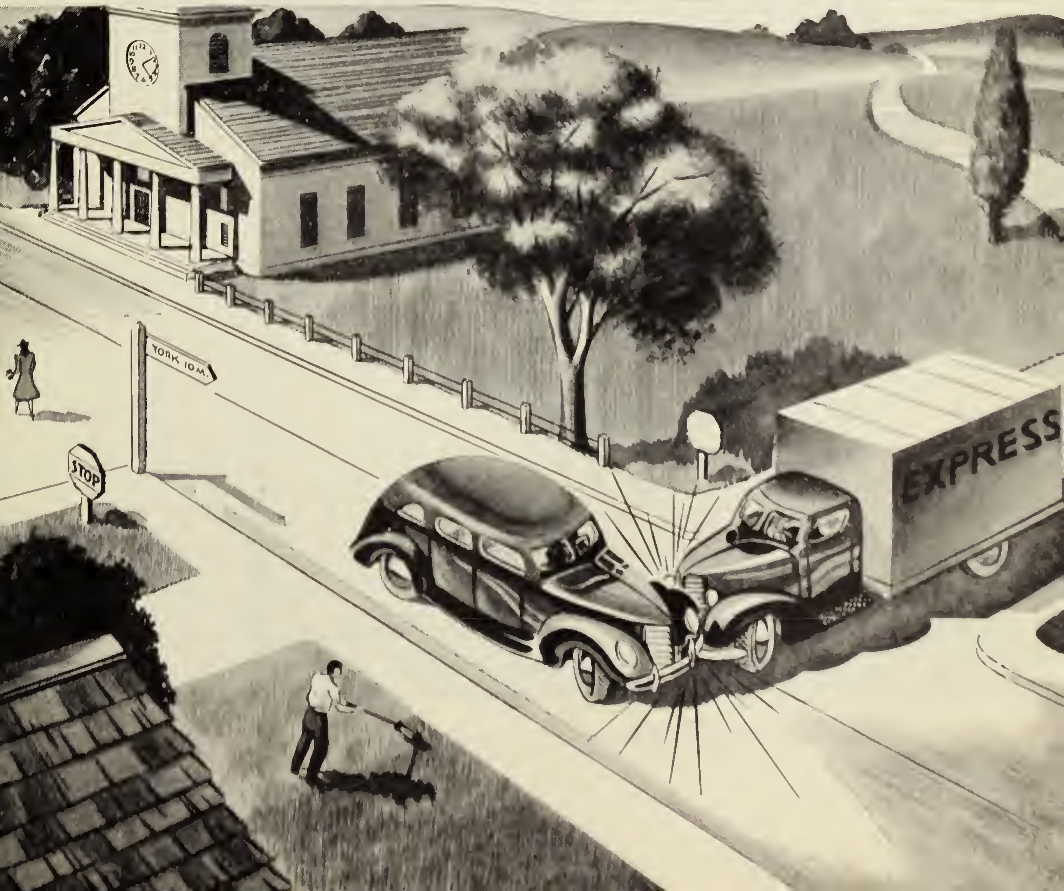
We look for another bird of the same kind. When we find one we are thrilled to see that it too has the heavy splotch of brown on its breast. We feel that we have made the observation that will identify the bird. We hurry back to the bird book and look through the pictures of the streaky brown birds. There it is, the very bird in the orchard! By careful observation we have identified the song sparrow.

The ability to observe accurately is not the same in all people. Some people are naturally better observers than others. Suppose you were in a position to see the accident pictured below. Look at the picture and see if you can tell which car was to blame. Make all the observations which you think might be useful if you were called into court to answer questions about the accident.

The following exercise will provide a further test for your power of observation.

Exercise. How to test your power of observation: Answer *from memory* the following questions: How many pockets are there in the coat or dress you are wearing today? What is the color of the dress your mother was wearing when you left for school? How many trees are there in front of your house? Are they all the same kind of trees? Are they all the same size? How many win-

How many observations can you make which might help a judge in deciding who was to blame in this accident?



dows are there in the kitchen of your house? Does the mailman carry the bag of mail on his right or left side? Was there a moon last night when you went to bed?

Perhaps these questions will show you that you are not as good an observer as you might be. Whether you are a good or a poor observer, however, you can make yourself a better observer by practicing observation.

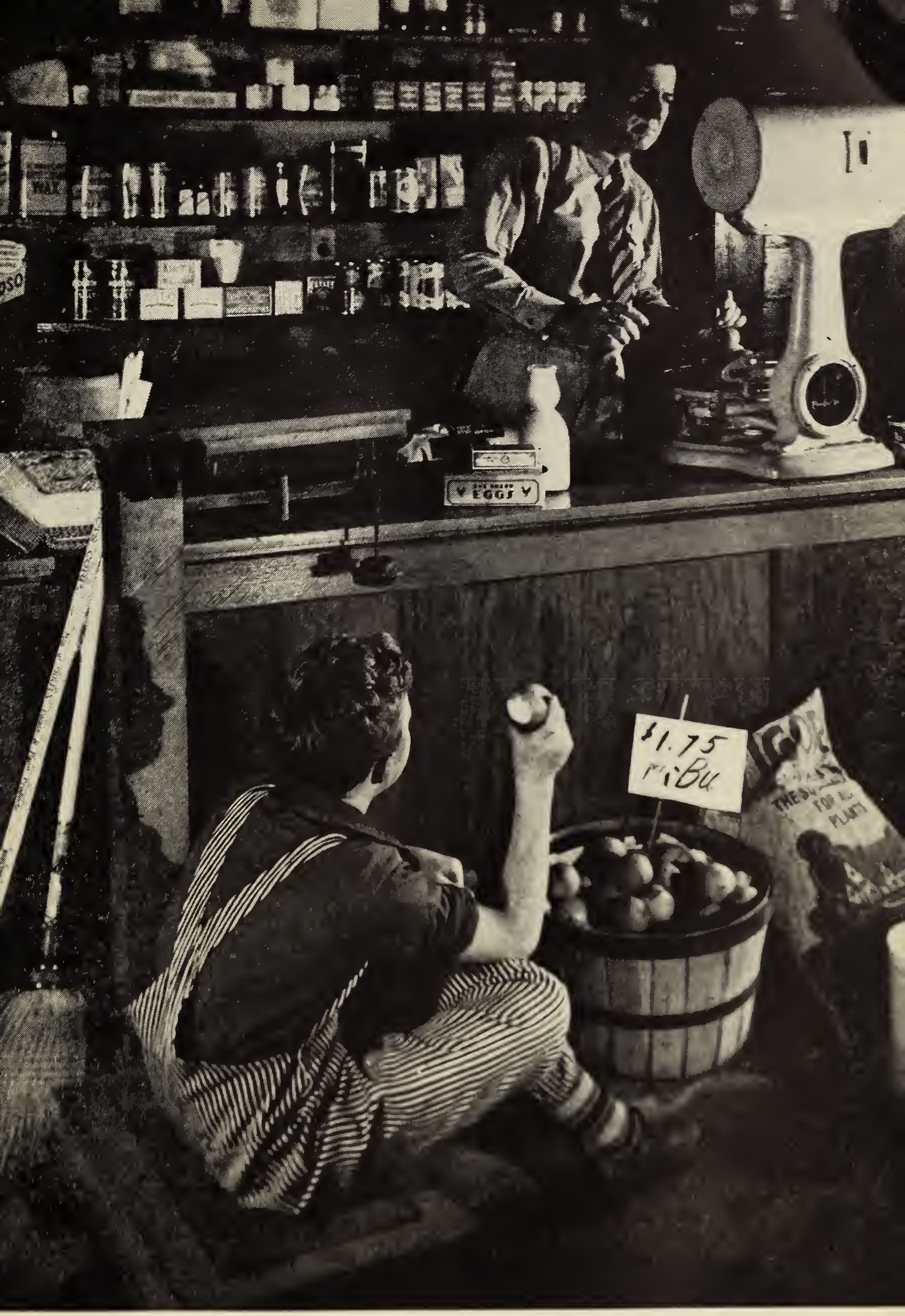
Exercises. How to strengthen your power of observation: Study the objects in your schoolroom very carefully *for five minutes*; then write the names of as many objects as you can remember. Compare your list with the lists of your classmates.

Study *for one minute* the objects on your dining-room table when it is set for dinner. Then go into another room and draw a sketch of the top of the table, showing each object where you think it is. Return to the dining-room and correct your mistakes.

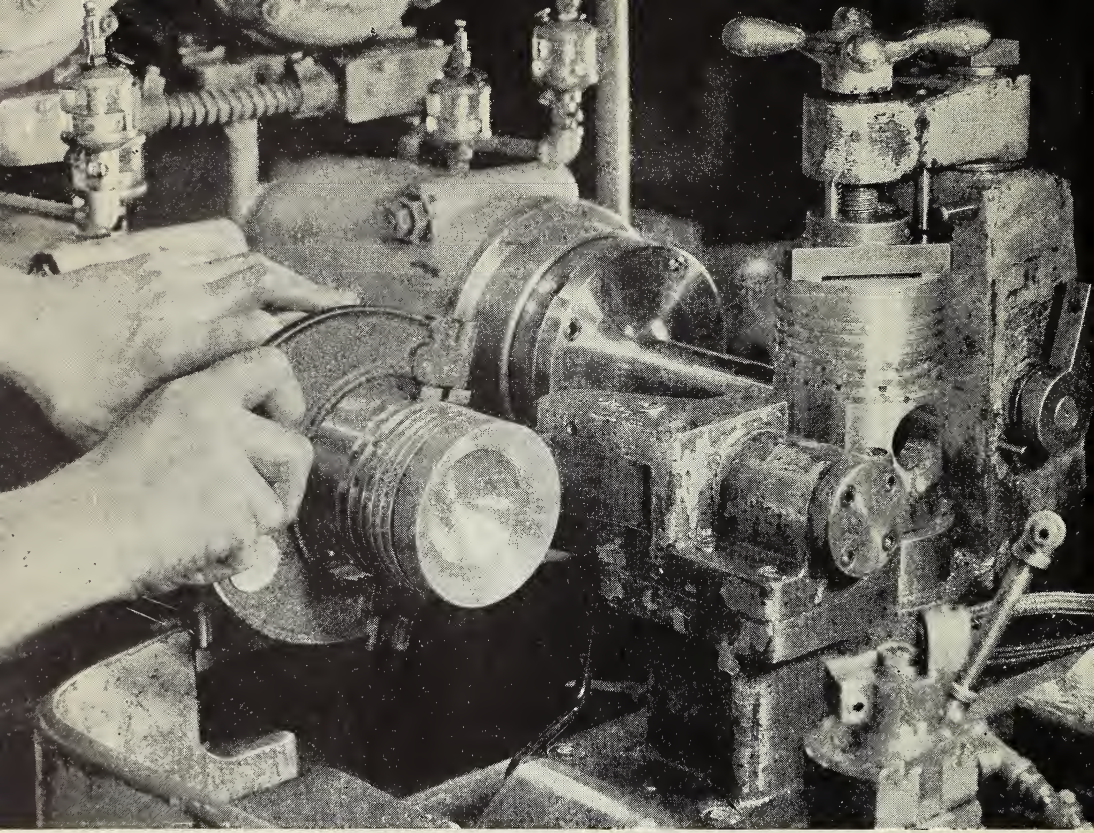
By making yourself a better observer you will make yourself a better scientist.

Measurement. It is often necessary in solving a problem to make very careful measurements. Take, for example, the problem of the age of the "big" trees of California. Scientists know that these trees are among the very oldest living things in the world. How did they learn this fact?

They learned it by a simple measurement. They knew from observation that a tree grows by adding a "ring," or cylinder of wood, around its trunk each year. When the tree is cut down, the rings, or cylinders, may be counted on the stump. The total number of rings is the age of the tree in years. Scientists found that many of the "big" trees of California have as many as two thousand rings. They were old when Columbus discovered America!



How many instruments of measurement can you find in this picture?



The moving parts of machinery must fit exactly if the machinery is to run smoothly. This man is using an instrument for measuring the diameter of an engine piston to a tiny fraction of an inch

Counting rings on tree stumps is only one method of measurement. There are many others, some of which we all use every day. When your mother does the marketing, she may bring home a *pound* of butter, a *quart* of milk, and half a *peck* of potatoes. She may return at ten *o'clock* on *September 9*, after having walked a quarter of a *mile*. The thermometer may show a temperature of 65 *degrees*. Each italicized word is part of a system of measurement which is in common use today.

Exercise. Make a list of all the measurements you have made or seen made during the past week.

Scientists, in exploring the mysteries of the world, have invented instruments of measurement which are marvelously accurate. One of these instruments is a balance which is so sensitive that it can weigh a pencil mark on a piece of paper. Another can measure the speed of light, which travels more than 186,000 miles a second. As we go on with our study of science we shall learn more about these instruments and their uses.

Experimentation. Many problems cannot be solved by observation and measurement alone. Experimentation, the third tool of science, must be used. Let us say that we have noticed a great number of little cream-colored grubs (wormlike animals) on a piece of meat which has been lying out in the sun. How did the grubs get there? Did they get into the meat the way small children believe that the rabbit gets into the magician's hat,—by magic? Or did they hatch from eggs which some animal had laid on the meat?

The best way of solving this problem is by experiment. We find a fresh piece of meat and place it in a dish. We tightly tie a fine piece of cheesecloth over the top of the dish so that no animal can lay its eggs on the meat. If grubs come to meat by magic, they will get through the cheesecloth without difficulty. If they come from eggs, the cheesecloth should keep them out by preventing any animal from laying eggs on the meat.

We place another piece of meat in a dish which is *not* protected by cheesecloth. We put the two dishes side by side in the sun. In three or four days the meat in the unprotected dish is crawling with tiny grubs, but the meat under the cheesecloth is without a single one. We have found by experiment that the cheesecloth keeps out the grubs.

How did the grubs come to the meat in the open dish? We suspect that the flies which have been swarming and walking over the unprotected meat may have laid their eggs on it, and that the eggs may have grown into the grubs. But why should flies have wormlike grubs for their young?

We perform another experiment to solve this mystery. We scrape off some of the grubs from the meat in the open dish and place them on the meat which is covered with cheesecloth. We watch them very closely. In a day or two they stop wriggling around on the meat. They turn into quiet little reddish-brown rods.

For a few days the rods look quite dead, but then a strange thing happens. A tiny fly crawls out of each little rod! Flies must have laid eggs on the meat that turned into grubs that turned into rods that turned into the little new flies. We have thus found by experimentation that the meat became wormy because it had been exposed to flies. We have also observed that flies pass through a grub stage and a rod stage before they grow wings and take to the air.

Today most people know that flies spoil food. They do not have to perform the experiments which we have just described. They do not have to do so, because an Italian by the name of Spallanzani performed the experiments for them many years ago. Before that time most people believed that flies and many other creatures had no parents; that they came to life by magic. They believed that food just naturally (or rather, unnaturally!) got wormy with time. But after Spallanzani made his experiments it was clear that food need not spoil if only it be kept clean.

Do you see how experimentation helps us to learn the truth about the world in which we live, and how it helps us to make it a better world to live in?

In the next chapter you will learn more about how experimentation has helped mankind find truth and better living. As you go on with your study of science you will perform many experiments yourself. *An experiment may be defined as an act planned to test, discover, or illustrate a truth.* Experimentation is one of the most important tools of science.

Good Thinking. With observation, measurement, and experimentation, we are almost ready to go to work on a problem in a scientific manner. We are not completely prepared, however, until we add the tool of good thinking. Without good thinking, all our other tools may fail to solve the problem.

Just what is good thinking? Let us solve a simple problem with the help of good thinking. One of your marbles has rolled under the piano. The first thing to do is to make sure that the marble has not rolled out at the side, or that it does not lie just under the edge of the piano, where it might be easily reached. In other words, *you first get a clear idea of the problem by observation.*

You next think of all the possible ways of solving the problem. You might try to move the piano off the marble, but you know that you are not strong enough for that. You might try to find someone strong enough to do it, but that would probably take a great deal of time because you are alone in the house. You might try to fish out the marble with your hands, but you can easily see that the piano is so low that you would be unable to squeeze your hand beneath it.

In other words, you think of several wrong ways of solving the problem. If you are thinking poorly, you will try each of the wrong ways as you think of it. If you are think-

How would you solve this problem?

ing well, *you will pass over the wrong ways without trying any of them.*

Presently you see a poker by the fireplace. "Just the thing!" you say to yourself. *You take a measurement* of the poker with your eye. It is about as long as the piano is wide. *Then you perform an experiment.* You lift the poker from its rack and run it along the floor beneath the piano until the marble rolls out.

You have solved your problem with good thinking, aided by observation, measurement, and experimentation. You have been a scientist.

Science and the Scientific Method. Do you see how we have now come to the answer to the question "What is science?" which is the title of this chapter? The use of observation, measurement, experimentation, and good thinking in solving problems is known as *the scientific method.* Knowledge gained through the use of the scientific method is known as *science.*

THE FUN OF SCIENCE

Think of the astronomer who has gazed at the heavens until he knows them as well as you know the people, houses, and streets of your home town. Suddenly a new comet flashes into the field of his telescope! Who does not envy him the thrill of that discovery?

Really, however, we need not envy him at all. The same thrill can be ours. All of us may be astronomers in the midst of a vast strange world. All of us may be Robinson Crusoes in a new land. Every day of our lives we see things that we do not understand. Even the most familiar things—like the rise of sap in a tree—become scientific problems if we become eager to understand them. The thrills of adventure and discovery await us on every hand.

Exploring the World around Us. The first great problem of science—which is really many problems—is to study

This boy is an amateur astronomer. He may possibly make an important discovery with the help of his telescope, and he will certainly have a great deal of fun

Los Angeles Board of Education

the world around us. Water, air, and earth make our lives possible. In countless ways they make us what we are. They make us do what we do. They are our neighbors throughout our lives.

In this book we shall study these neighbors and try to learn about them. We shall explore the world we live in. We should find it an exciting adventure. We should find that the world is indeed so full of a number of things that we surely should all be as happy as kings.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The scientist of the modern world and the wizard of the fairy tale are alike in many ways.

2. It is impossible to be a scientist without a laboratory full of expensive instruments.

3. Rabbits and men are the same kind of creatures because both eat vegetables and live under some sort of shelter.

4. It is very difficult to find problems to solve because scientists have already found and solved so many.

5. Scientists have so many exact instruments that they no longer have to use their own power of observation.

6. Most instruments of measurement are too difficult for boys and girls to understand.

7. Making experiments is a foolish waste of time because there are other more reliable and quicker ways of finding truth.

8. People always knew that flies spoil food.

9. It is part of good thinking in solving a problem to try every possible solution that pops into your head.

Questions for Discussion

1. Think of a problem you have recently had to solve. Discuss with your classmates the way you solved it, and decide whether or not you used the scientific method.

2. Think of a possible problem concerning each of the following: a garden, preparing a meal, driving an automobile, playing a game. Discuss the best way of solving each problem.

Things to Do

1. Read the story of the life of some scientist in whom you have been interested. Your librarian at school or in your community library will be glad to help you find it. As you read, try to decide what contribution the scientist made to the world and what effect his life has had upon our lives today. The results of your work might be presented to your class as a science talk.

2. Keep a "science" diary. Every day write a brief account of the new things you have learned through the use of the scientific method.

3. Keep a "bad thinking" diary. Every day write a brief description of the problems you have seen people try to solve in an unscientific way. Explain in each case why you think the method was unscientific.

4. Write an explanation of what you understand science to be.

CHAPTER TWO

What Has Science Done for Us?

THE AGE OF SCIENCE

Five Days in Less than an Hour. At the airport of a Western town a group of people were crowded eagerly about an excited old man. No longer were they interested in the take-offs and landings of the planes about them. They forgot everything else as they listened to the old man's story.

For months he had been hearing about an airline between this town and another town a hundred miles away. Well he knew that route by land. As a young man he had many times carried goods over the forest cart paths and across unbridged streams to the "settlement" down the river. Five days and more it had taken him to make the journey.

Recently he had been told that the airplanes which he had seen sailing so gracefully over the land were making the same trip in less than an hour! And so this morning he had come down from his little home in the hills above the town to see for himself if the stories about these strange new flying machines were true.

He had found them true indeed. He had actually just made a round-trip journey over the route in an airplane, and it was not yet noon! Proud and excited over his experience, he was telling the people about the time when he had made the same trip with horse and wagon. This morning he had traveled by air! Breaking away at last from the curious crowd, he shook his head and was heard to say to himself, "Five days in less than an hour! What next?"

No one knows "what next" in a world of discovery and invention. Not a bit less remarkable than the recent progress in aviation are the finding of cures for diseases which were once thought incurable; the discovery of more healthful and more appetizing foods; the development of improved methods for transporting food; the discovery of new planets and far-distant universes; and the invention and improvement of radio. Within the last fifty years discoveries and inventions have been very numerous. Men of science are learning new things every day.

The Modern Age. It is often said that we live in an age of science. If we look around us, we can easily prove that this is true. Books, magazines, and newspapers are full of news about all sorts of everyday happenings in the world of science. If you should keep a list of what you read in science over the short space of a week or two, it might include any or even all of the following items:

Daily weather reports
Stories of new records made in aviation
Descriptions of new machines or of improvements in old machines
Reports of flower shows, garden clubs, or cattle shows
Accounts of new discoveries in medicine
Information about the stars, the planets, a coming eclipse, or even a comet
Historical sketches of important discoveries or stories about the lives of famous men, such as Edison, Bell, Einstein, and others

Exercise. Make a collection of newspaper clippings about interesting new discoveries and inventions. Are these clippings easy or hard to find?

By using the methods of science, man has gained more and more knowledge about the world in which he lives. Through this knowledge he has already been able to invent many clever machines for using the things around him. He has already been able to discover many clever ways of suiting himself to things he cannot change.

To learn how scientific our age really is, let us take a short mental journey through the unscientific ages of the past.

THE AGES BEFORE THE AGE OF SCIENCE

The Cave Man and the Storm. Imagine yourself a man of many, many years ago. Your home is a gloomy cave. You sit huddled with your family round a small smoky fire in the middle of the floor. Outside, the night is softened by the pale glow of the moon.

Suddenly blackness erases the outside world. The light of your fire throws strange, flickering shadows upon the walls. A feeling of uneasiness creeps over you. In the distance you see a flash of lightning as it touches the edge of a mass of dark wind-driven clouds. You hear faint rumbles of thunder. The wind is sobbing in the trees. A few drops of rain sprinkle the ground and rattle on the dead leaves. The lightning becomes more vivid, the thunder louder. You see the clouds as they drive on, tumbled black masses which blot the stars from the sky.

Now the storm breaks in real earnest. Brilliant flashes of lightning zigzag across the sky. Terrific crashes of thunder blend in a deafening roar. Driven by the gale, wind lashes the forest, and torrents rush down the mountain side. Trees above you are uprooted. A pine close by is shattered in a blinding streak of lightning. You crawl back into your shelter to wait in fear for the dawn.

The next day you are still wondering about the night before. You ask someone, possibly an older member of the tribe, for an explanation. He reminds you that a few days ago you killed a deer, and that in your hurry to get home you forgot to make an offering to the favorite god of the tribe.

The god became very angry, the old man explains, and sent the storm to punish you. Trembling with fear and hoping that it is not yet too late, you hasten to make the offering. There are no more severe thunderstorms for several months, and you decide that you did the proper thing. You decide that the old man who told you to make peace with the angry god was very wise.

Science has saved us from the hardships, dangers, and fears of the cave man's life

Galloway

We may not always like what our leaders do,
but who would prefer to be led by this primitive "wise" man?

How Magicians Are Made. You go to the old man more and more for advice about how to live. Perhaps all in the community of cave men decide that it would be a good thing if the old man would spend all his time giving advice. Certainly somebody should spend his time finding how to keep friendly with the gods who control us and the world we live in. Somebody should explain the strange things that happen from day to day.

In order that the old man may not be disturbed, all sorts of rules are set up. None of the tribe is allowed to visit him except on special occasions. Food and other necessities are given to him. Certain ground is sacred to him alone. Here he is to meet with the gods for your benefit, and no one else may go near the place for fear of offending the gods. Soon the old man becomes the most powerful man in the tribe, respected and feared because everyone thinks he has influence with the gods. *The old man has become a magician.*

The Power of Ancient Magicians. In many of the pages of history you will find the magician engaging in his secret practices. He has not always been called a magician. He has been known as medicine man, soothsayer, astrologer, and witch doctor. But whatever his name, he has been the "wise man" to whom people of many ages have gone for help in times of trouble and fear.

As his power increases, the "wise" man is asked more and more difficult questions. What is the sun? Why do we have day and night? Where does the rain come from? What causes heat and cold? Not knowing, in most cases,

Here is an ancient explanation of why the winds blow.
It is simple, dramatic, and untrue

Courtesy Compton's Pictured Encyclopedia

Here is an ancient map of the earth which served better to scare sailors than to teach them geography

the true reasons, he invents more and more fantastic explanations for simple and natural things.

You have probably read about many of these. The sun, to one tribe, was a polished plate of bright metal which was carried through the sky by a faithful god whose duty it was to see that the earth had heat and light. At the close of the day the plate was taken home and put away. While the god rested from his labors, night crept over the earth.

Even after men had become civilized, they kept many of the beliefs of the ancient magicians. Many old maps of the world, such as the one on page 30, show pictures of the wind gods with cheeks filled to bursting as they blew over land and sea. For a long time the earth itself was thought to be flat and saucer-shaped. Ships that failed to come back after a voyage were thought to have plunged over the edge of the world. The picture above shows this early belief.

Beliefs of this sort seem very foolish to us now, but once they were matters of life and death. Many people lost their lives or were horribly tortured because they dared to doubt some opinion expressed by the so-called wise men of the tribe.

Science and Superstition. We saw in the last chapter that scientific beliefs are based on observation, measurement, experimentation, and good thinking. The beliefs of the ancient magicians were based on none of these things. *They were based on feelings, and especially on the feeling of fear.* Such beliefs are now known as superstitions.

Superstitions are hard to kill. In spite of the great change in beliefs which science has brought about, it has not succeeded in wiping out all fear and superstition. If you have ever been on a farm, you may have heard that horsehairs left in a watering trough would turn into snakes. If you asked for more information, you were probably told that because the "horsehair snakes" look like horsehairs they must really be horsehairs that have come to life. A careful study of these creatures proves that this explanation is entirely false. No horsehair ever turned into a snake.

Of course you have heard about the wonderful hoop snake. It can put its tail in its mouth, so the story goes, and roll off faster than a horse can run. Have you ever seen a hoop snake doing this? Do you know of anybody who really has? There are many such stories that are nothing but superstitions. They are started and carried along because a friend of someone has a friend who knows a man who did see something like it. There is no snake, nor any other animal, that travels by rolling like a hoop.

There are countless other ideas of this kind. Many people have searched for good places to dig wells by carrying a forked willow twig in their hands. When such a "water witch" bends suddenly toward the ground, some people still think that it does so because it is strongly attracted by the water in the ground. There are no facts to support such a belief. Scientists know that you will find water almost anywhere provided you dig deep enough.

Many of these beliefs seem ridiculous to you, but a great many people are still superstitious in some way or other.

Look at page 34. Some people are afraid to walk under a ladder. Some believe they will have seven years of hard luck if they break a mirror. Some fear Friday the thirteenth. Many hotels skip the number thirteen in marking the floors because so many people are superstitious about the number thirteen. Some people turn back from a trip if a black cat crosses their path as they start out. Some are afraid to handle a toad because they think toads cause warts. *There is no evidence that any of these beliefs is true.* They are all superstitions, inherited from the ages before the age of science.

Many superstitions have to do with the causes and cures for illness. To cure a wart on your hand, for example, you must steal five beans,—a bean for every finger. Tie the beans carefully in paper and carry them to a place where two roads cross. Then drop them and walk away, without ever looking back. The warts will leave you for the hands of the person who picks up the beans.

Every year hundreds of thousands of dollars are spent by people all over the world in visits to palmists, astrologers, crystal-gazers, and other kinds of fortune-tellers. Like the medicine men of time long past, these modern witch doctors sell good-luck charms, secret spells to be repeated at midnight every third day, and a host of other silly things which are taken seriously by thousands of people. In some cases these medicine men of today are honest but ignorant. In most cases they know very well that they are merely taking advantage of their customers.

Exercise. Take stock of your beliefs and make a list of those which you consider partly or wholly superstitious. Make a plan for getting rid of each superstition with the help of the scientific method.

SALT

HOW SCIENCE HAS CHANGED THE WORLD

Science Was Born of Doubt. Science came to a superstitious world when people began to doubt. It came when they said to their "wise" men: "I wonder if that's right?" "What do you really know about this?" "What proof have you of that?" "I'll check up on this and see if it is true." Once doubt had entered the minds of the people, good thinking was able to take the place of bad thinking. Science was able to take the place of superstition.

The Dawn of Scientific Thinking. Again imagine yourself a primitive cave man. You believe many things, most of them the result of training by the "wise" men. You believe that your tribe is the only race of people on earth. The earth itself, you have been told, extends only so far as a two days' journey from your village. One day a member of your tribe goes on a hunting trip and does not come back. After several weeks your medicine man tells you that this hunter has been killed because he went into a part of the country forbidden by the gods. You believe the "wise" man and never expect to see the hunter again.

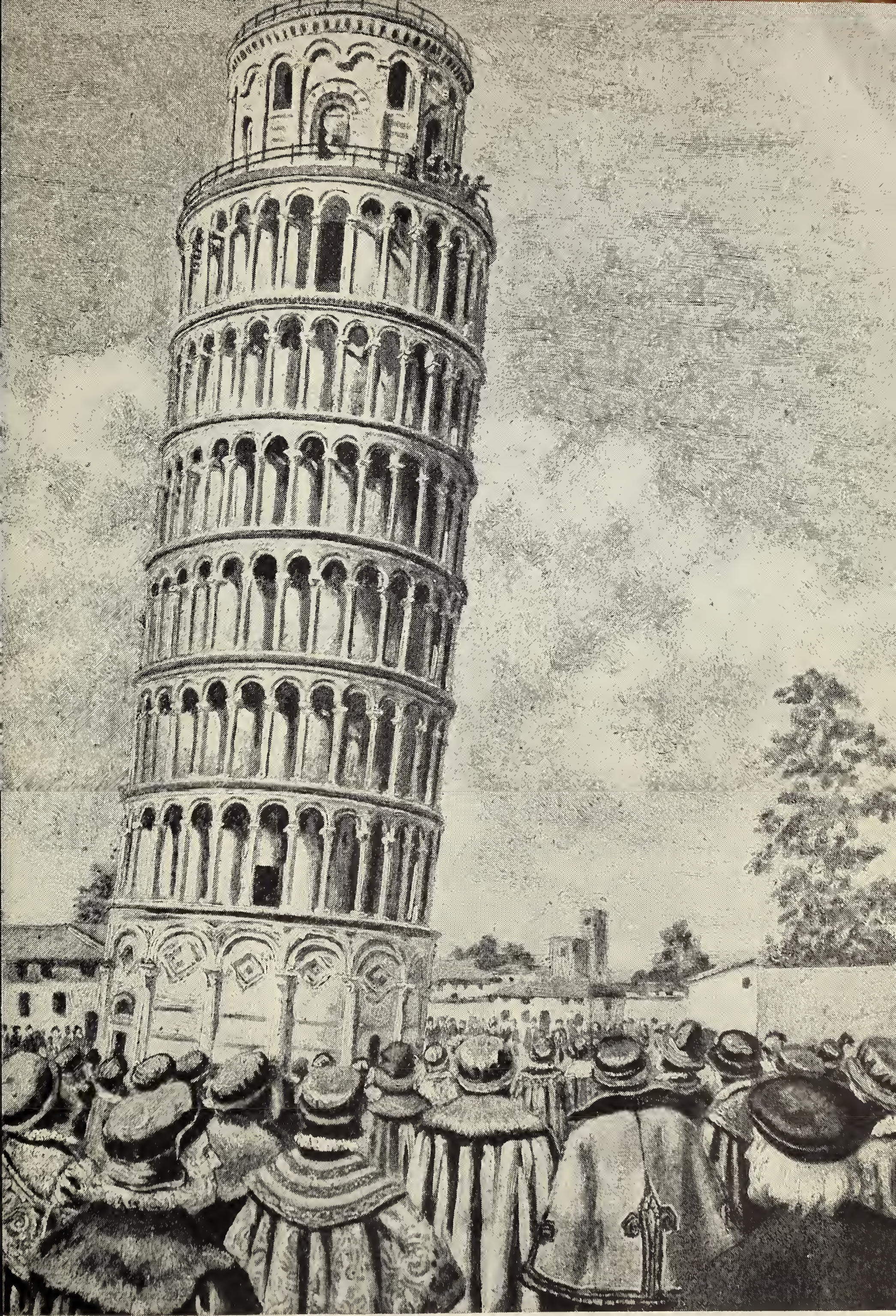
One day months later the hunter comes back. He is not only safe and sound but he has a wonderful story of the strange people and the new countries he has discovered far away from home. Have you as much faith in your so-called wise man now as you had before? Perhaps you feel that if the "wise" man is wrong this time, he has been wrong about some of the other things he has told you. Perhaps you decide that from now on you are going to try to work out your own explanations for things that you do not understand. Perhaps you decide that you will try to find proof for beliefs before you accept them as true.

In some such way human beings first learned not to believe all they were told. When people seek proof for their beliefs, the methods of science are substituted for practices based upon superstition. In your study of science you will learn to seek—and to find—proof for many things.

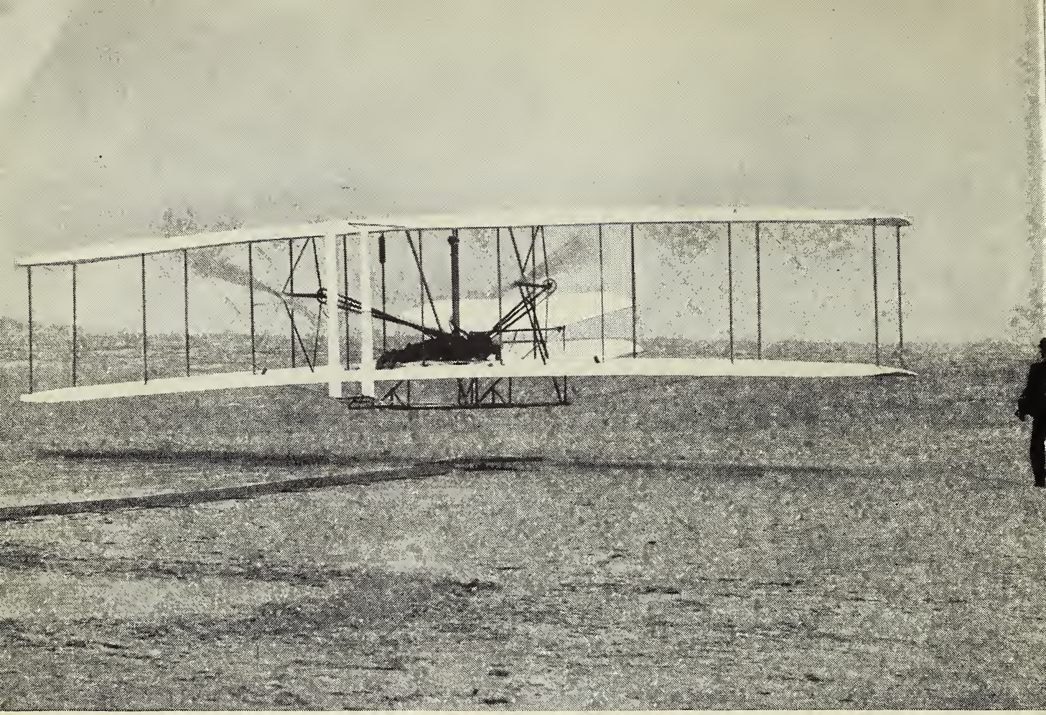
Galileo's Experiment. The history of science is full of examples which illustrate how the use of the scientific method has changed beliefs of long standing. The story of an outstanding pioneer in scientific study may be found in the life of Galileo. As a young man Galileo was professor in the University of Pisa in Italy, some three hundred and fifty years ago. About two thousand years before Galileo's time, Aristotle, a Greek, had taught that if two objects, like two balls or rocks, are allowed to fall to the earth, the heavier object will fall faster. This was still accepted as true by many people in Galileo's day, but Galileo himself had doubts.

It is said that he decided to test the truth of the belief by an experiment. He carried two round weights, one of which was very much heavier than the other, to the top of the Leaning Tower of Pisa. He dropped the two weights at the same instant from a window in the tower and observed that they fell *at the same speed*, and struck the ground at the same time. Thus Galileo proved scientifically that Aristotle was wrong. This is one of the most famous experiments in history because it was one of the earliest known attempts to test the truth of a common belief by the scientific method.

The Age of Science Has Just Begun. Since the time of Galileo science has gone ahead in leaps and bounds. Most of the discoveries and inventions in science are very recent.



How Galileo exploded a common belief by experimentation



The first airplane flight took place less than half a century ago

We think nothing today of picking up a telephone and calling our neighbors at the other end of town. On special occasions people talk with relatives or friends at the other end of the continent and even on other continents. Yet the telephone is only a little over fifty years old. When Alexander Graham Bell first succeeded in sending the human voice over a wire, his invention was looked upon as an interesting "stunt" but of little practical importance. Now it is a part of our everyday life.

Today the airplane is so common that even a new flight across the Atlantic or the Pacific fails to create much excitement. Yet the first flight of man in a motor-driven machine was made by one of the Wright brothers in 1903, about forty years ago! That first flight lasted only a few seconds. Today airplanes fly for hours without stopping, over thousands of miles of land and sea.

The first successful trip of a locomotive on rails was in 1803, a mere hundred years before the first successful flight of an airplane. Robert Fulton's *Clermont*, the earliest successful steamboat, first puffed its way up the Hudson River in 1807. As late as 1895 only four automobiles had been produced in the United States. On page 40 you will find a list of inventions which have made our age quite different from all earlier ages. Study the list and note that all the inventions fall well within the relatively brief period of the last century and a half.

Today we tend to take these and other inventions and discoveries for granted. Yet most of them are less than a century old. Consider the life of such a family as the one shown on page 28. It is certain that such people had few of the comforts which have resulted from the work of scientists in recent times. They did not have the variety of food and clothing or the safe and comfortable shelter, transportation, and communication that we enjoy today.

The first successful steamboat was built less than a century and a half ago

SOME EVENTS IN THE HISTORY OF SCIENCE	
1803	The first Steam Locomotive ran on rails
1807	Fulton began Steamboat Travel on the Hudson River with the *Clermont*
1824	Aspdin patented Portland Cement
1834	McCormick patented his Reaper
1844	Morse sent the first Telegram
1856	Bessemer announced a new process for making Steel
1867	Lister announced a method of Antiseptic Surgery
1874	The first successful Typewriter was put on sale
1876	Bell sent the first Telephone Message
1877	Edison first reproduced spoken sound by the Phonograph
1878	Edison introduced his Carbon Electric-Light Bulb
1882	The first Commercial Electrical Power Plant was placed in operation
1884	Parsons tested the first model of his Steam Turbine
1885	Mergenthaler patented the Linotype
1895	Four Automobiles were produced in the United States
1901	Marconi sent and received the first Wireless Messages across the Atlantic Ocean
1903	Orville Wright flew the first Motor-driven Airplane
1905	The first Motion-Picture Theater was opened in the United States
1907	De Forest patented the Radio Tube
1919	The first Nonstop Flight was made across the Atlantic Ocean from west to east
1920	The first Autogiro Airplane was flown
1924	Cross-country day and night Air-Mail Service was begun
1927	Long-distance Television was first shown to be possible in a test between New York and Washington

The Greatest Gift of Science. What is the greatest gift of science to man? Some people might argue for this invention and others for that. But you who have studied this chapter should know that no single discovery or invention is the greatest gift of science to man. You should know that *the very greatest gift is the scientific method.* It made *all* the discoveries and inventions of science possible.

You are now standing on the doorstep of the house of science. This book is a guide that will show you what is inside. It will teach you many important facts about yourself and your world. But the most important thing it can hope to teach you is the scientific method of solving problems,—the method of observation, measurement, experimentation, and good thinking. By this method men have come to know much of what they now know about themselves and their world. By this method they may hope to learn much more in the future.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Discovery and invention are slowing down today because most of the possible discoveries and inventions have already been made.

2. In the ages before the age of science men lived closer to nature than they do today and therefore knew more about nature.

3. The ancient magician was respected because he was wiser than other men.

4. Primitive men had a correct idea of the shape of the earth.

5. With the age of science, superstition vanished from the world.

6. The "water witch" was a useful scientific invention made long before the age of science.

7. The people of ancient times had beliefs about the habits of the hoop snake which later scientists have proved true.

8. Modern science grew out of the wholehearted devotion of the ancient medicine men to truth.

9. Scientific thinking began when the medicine men began to doubt the old explanations of common happenings.

10. It has been a well-known fact since the time of Aristotle that a heavy rock will fall faster than a light rock.

11. The first successful steamboat was put into operation four years before the first successful locomotive.

12. Undoubtedly the greatest gift of science to man is the lengthening of human life.

Questions for Discussion

1. It is said that people today lead more comfortable lives than they once led, physically as well as mentally. Can you give some examples of how we are living more comfortably now than people lived a hundred years ago?

2. Could you use the experimental method to find out whether or not toads cause warts? Could you prove experimentally that horsehairs do not develop into "horsehair snakes"? How?

3. It is said that knowledge drives away fear. Can you give an example of this?

4. Should you be suspicious of statements made by a person who never says "I don't know"? Why?

Things to Do

1. Start a class scrapbook of clippings and stories about superstitions of today. Add to this as you find more examples.

2. Read *The Story of Ab*, by Stanley Waterloo. This is about a boy who lived in a cave thousands of years ago. As you read it, compare his ways of living and thinking with your own. Make two lists, one showing the ways in which Ab did certain things, and the other the ways in which you would do the same things. You might point out how science has changed the ways of doing these things.

3. Organize a weekly or monthly science newssheet. You can arrange it in the form of one or more posters with news columns, pictures, drawings, and so on, and keep it on the bulletin board. The news columns can be written in longhand or on a typewriter, and the pictures and drawings can be pasted on the poster. The whole newspaper should be arranged as attractively as possible. You might call your publication the "Scientific Age," or some such title.

4. You can probably put on a magic show and do some tricks that will illustrate how magicians fool the public. Such a book as R. F. Yates's *Boys' Playbook of Chemistry* may help you.

5. You may want to read Van Loon's *Man the Miracle Maker*. In this book you will find the story of man's progress from the days of long ago. The pictures look just like those you might like to make.

OUR WORLD IS SEVERAL WORLDS

We are now ready to explore the world with the aid of the scientific method. But where shall we begin our explorations? The world is a very large place and full of many things. We must not just wander about, because such wandering is not exploration. It is merely being lost.

◆

If we look carefully at the earth on which we live, we can see that it is not one world, but several. It is rivers, lakes, and oceans, *a world of water.* It is wind and the gases we breathe, *a world of air.* It is mountains, plains, and soil, *a world of rock.* It is plants, animals, and human beings, *a world of living creatures.* It is movement and change, *a world of action.*

◆

Each of these worlds is in some ways separate from all the other worlds. Each has its special conditions, its special problems. As a help to your explorations we have divided this book into units, one unit for each of the worlds of which our world is made. In this way you will have a plan of exploration. You will not get lost in the wilderness you are trying to map.

◆

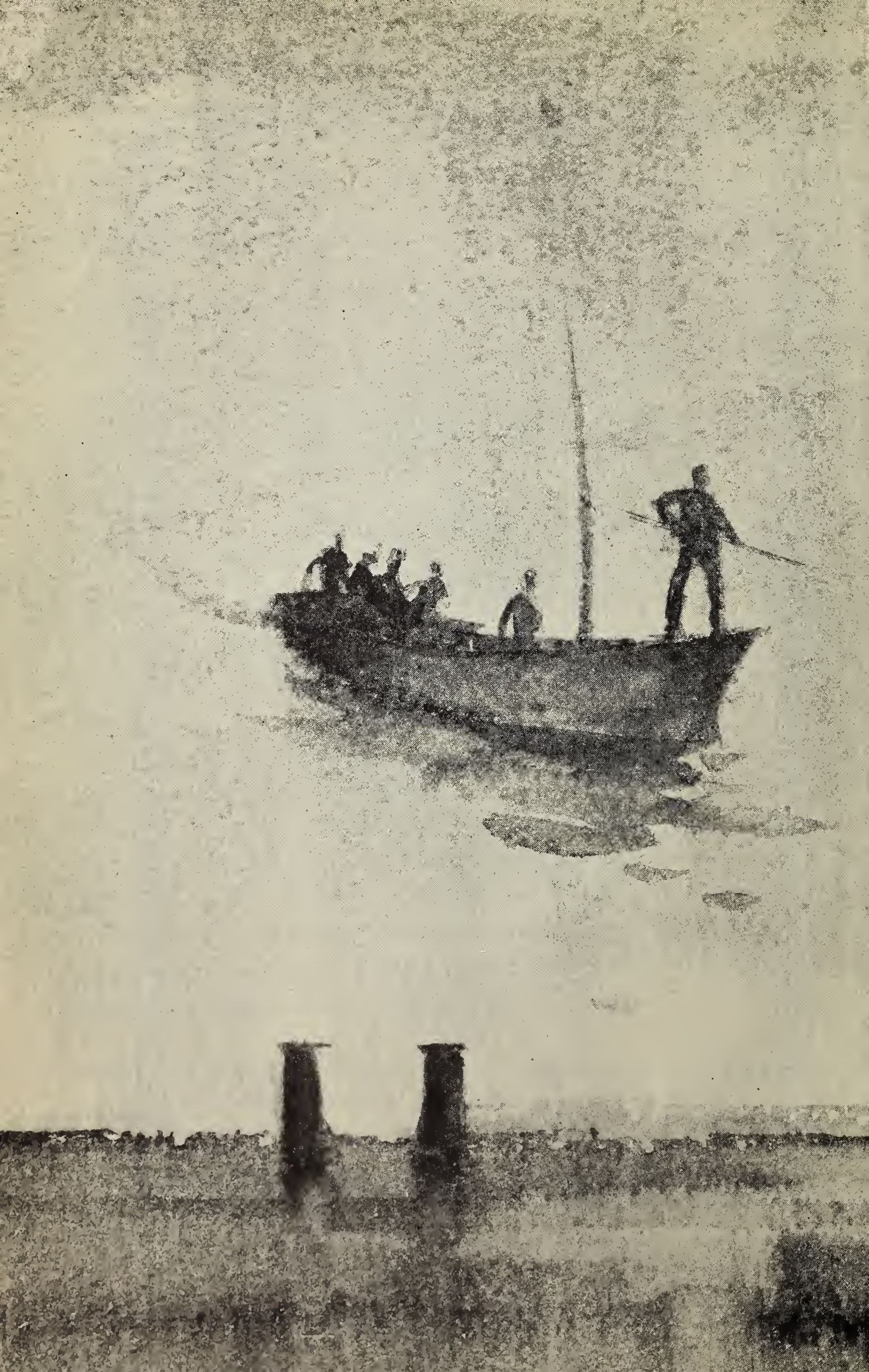
Though our world is truly several worlds, we must never forget that it is *several worlds in one.* Water, air, rock, living creatures, and action are mingled in such a way that they can never be really separated. We shall consider them separately only for the purposes of exploration. In doing so, however, we shall constantly be reminded that the worlds are everywhere and always mingling with one another. In this way we shall explore each world in its turn, and at the same time learn how all the worlds fit together into one vast world.

◆

Which of the several worlds shall we explore first? Scientists have good reasons for believing that life first appeared long ages ago in the waters of the earth. Why should we not begin our explorations where life itself began,—in the world of water?

UNIT TWO

THE WORLD
OF
WATER



EXPLORING
THE WORLD OF WATER

We all know that water is necessary to life.

But exactly how and why is it necessary?

◆

We all see water every day

But exactly what *is* water and what does it do?

◆

We generally get all the good water we need.

But exactly how do we get it and how do we make sure that what we get is good?

◆

We all know that water works for us.

But exactly how and where does it work for us and how do we benefit from the work?

◆

Unit Two of this book is about to explore the world of water in search of the answers to these questions. Shall we go along?

CHAPTER THREE

Is Water Necessary to Life?

THE NEED FOR WATER

Life in the Sahara Desert. Let us imagine ourselves at the edge of the Sahara Desert. The temperature in the shade has reached one hundred and ten degrees. We are resting at an *oasis* where water bubbles in precious little springs at the surface of the parched land. Palm trees stand round the springs, their feet in the water, as the Arabs say, and their heads in the sun of heaven. How pleasant their cool shade feels!

Looking toward the south beyond the oasis, we see a caravan of Arab traders coming our way across the dry and treeless waste. Hundreds of men and camels make up the caravan, which stretches in a long line across the desert. Our guide tells us that these men have brought dates and other products across the wind-swept sands and rocky plains from Timbuktu, nearly fifteen hundred miles away. Now they are nearing the shore of the Mediterranean Sea, the end of the trail. They have been many weeks on their journey.

They have crept along slowly from one oasis to the next. Sometimes they have traveled as many as three or four days without seeing a single growing plant. During the blazing heat of midday they have had to rest, for the heat is then too great for any work. We marvel at the strength of the men and their camels. Unaccustomed to desert hardships, we ourselves could probably not live through a similar experience.

Three Lions

This is a typical oasis, water's precious gift to the desert traveler

But now there is rest for the weary travelers. Here in the oasis is water! Date palms offer clusters of delicious ripe fruit in welcome. Oranges, grapes, and fresh vegetables are abundant. These and many other growing things await the travelers in such an oasis as is shown above.

What makes the difference, we ask, between this little oasis of green plants and the barren lands which lie around it as far as the eye can see? We can answer our questions in one word,—water. Here is water and here is life. Out in the wastes of the desert there is little water and therefore little life.

Deserts are found in many countries. In Africa is the Sahara Desert, which we have just described. In Asia we find The Gobi, in Australia the Great Victoria Desert.

Even some of the Western states in the United States have desert lands. These and other similar places are almost uninhabited. Life is scarce when water is scarce.

Exercise. What do the conditions in desert lands prove about the importance of water to living creatures? If all lands were deserts, would there be as many people on earth as there are? How would their lives be different from ours?

How Greatly Do Plants Need Water? By observation of conditions in desert countries we have discovered something of the general need for water in the lives of living creatures. Let us now make an experiment to see if we can discover exactly how great this need really is.

Exercise. How to determine a plant's need of water: Secure two plants of the same kind and as nearly the same size as possible. Small house plants or a seedling of corn or bean will serve. The two plants should be growing in pots of the same size. Each pot should contain the same kind and the same amount of soil. Water one of the plants regularly and care for it as usual. The other is not to be watered for at least three days. Each day compare the watered with the unwatered plant. Make notes on your observations. After a few days (not over a week) set the unwatered plant in a pan of water. Note the changes that then take place.

The following questions should be answered during the course of the experiment: (1) What has happened to the unwatered plant at the end of the first day? (2) at the end of the third day? (3) at the end of the sixth day? (4) What happens after it is watered? (5) Why was a watered plant needed in this experiment? (6) What have you learned from this experiment?

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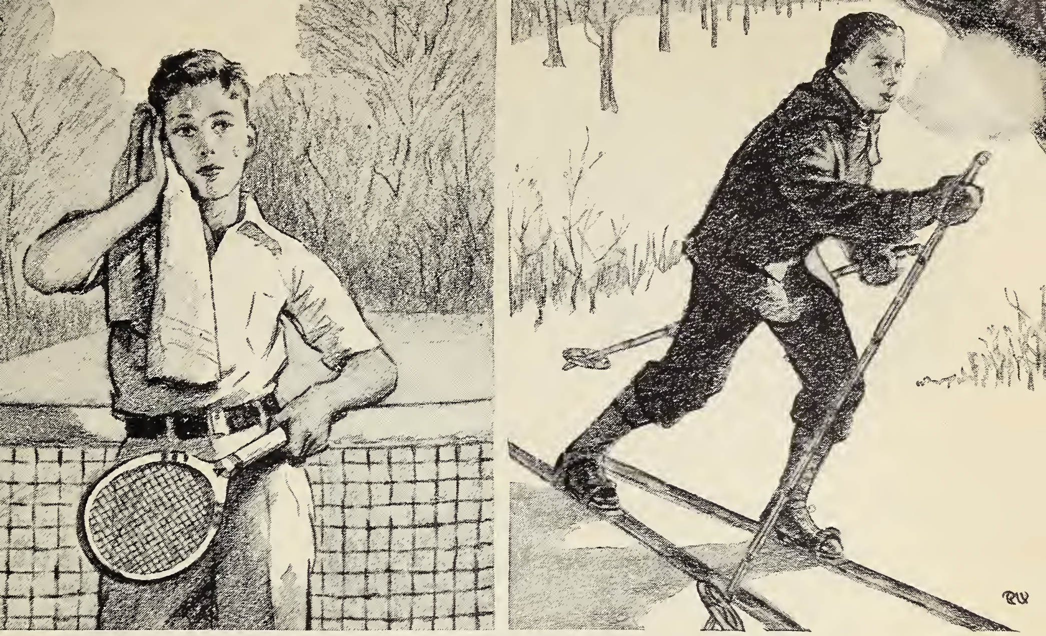
OF ALBERTA

Why You and I Need Water. While waiting for the results of the experiment with the plant, let us study our own need for water. No experiment is necessary to prove that need. We all know how unpleasant it is to be thirsty! Thirst is the way our bodies cry for water. But why do they cry?

Our bodies are made of millions and millions of little units called *cells.* We shall study these cells more closely later. Now it is only necessary to know that these tiny cells must all be regularly fed and bathed if we are to continue to live and be healthy. *Water not only helps feed and bathe the cells of our bodies but it is also to a large extent the material of which the cells are made.* If the water were squeezed out of the flesh and bones of an average-sized man, twelve or thirteen *gallon* containers would be necessary to hold it. Naturally we get "thirsty" for water when the supply in our bodies runs low. We can no more operate without water than an automobile can operate without oil.

How Water Circulates in Our Bodies. When food enters our stomachs, it is churned fine and mixed with water. As it travels through the intestines it is thoroughly dissolved in water. In this state, and only in this state, can it pass through the walls of the intestines and into the blood. The blood, which itself is mostly water, then carries the dissolved, or *digested,* food to every cell in our bodies.

Waste products are developed in the cells every day of their lives. Water which faithfully helps to feed the cells also helps to rid them of this waste. *It does so in three different ways.* Some of the waste is carried in water to the kidneys and then expelled from the body. Some is expelled with water through the skin by perspiration. Some is expelled with water from the lungs. The air you breathe out is always more moist than the air you breathe in. When



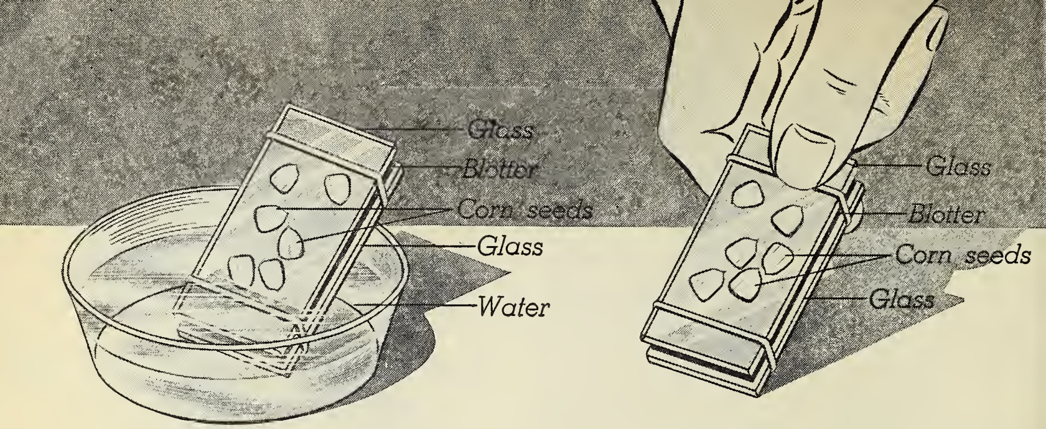
We lose water from our bodies both summer and winter

you "see your breath" in cold weather, you are really seeing the moisture in it. The drawings above show two ways in which water is lost from our bodies.

How Lost Water Is Replaced. The water which is lost through the kidneys, skin, and lungs must be replaced if life and health are to be preserved. At some times we lose more water than at other times. As a result we are thirstier at some times than at others. We find ourselves drinking more water on hot days than on cold days, more after vigorous work or exercise than when we are quietly studying or reading.

Exercise. Why do hot days and vigorous exercise make us thirsty?

Some of the water which is lost from our bodies is replaced by the liquids in the foods we eat. Green vegetables and fruit are roughly from 80 to 90 per cent water. Milk is about 80 per cent water, and meat from 50 to 75 per cent.



Here is a good way of discovering the effect of water on seeds

Exercises. How to determine the amount of water in green vegetables: Secure a pound of some green vegetable, such as spinach, cabbage, or lettuce. Place it in a covered cooking pot. After it is well cooked, take out what is left of the vegetable, squeeze it as dry as you can through a strainer, and weigh it. How much weight did it lose? What did it lose? What percentage of its original weight was water?

Cut several apples into small pieces, weigh them, and spread the pieces on a paper in the sun. If you do not have bright sunshine, place the cut apples in an oven or over a hot radiator. After they are dry, weigh them. How much did they lose? What did they lose? What percentage of their original weight was water?

Since we need more water than we get through our food, we are advised to drink plenty of water every day. The normal grown person needs from six to eight glasses of water a day. Not all of this should be taken with the meals. Neither should it be ice cold, for the shock of an ice-cold liquid may be harmful to the warm and delicate lining of the stomach.

Other animals, as well as plants, use water in much the same way that we do.

Exercise. How to discover whether dry seeds will sprout: Get several seeds (bean, corn, pea, nasturtium, or any other fairly large seeds will do). Put them on a blotter between two glass slides, as shown in the drawings on page 54. Make two sets. Stand one in a dish of water. Allow the other to remain dry. Write a description of what water did to the one set of seeds and what lack of water did (or failed to do) to the other set.

CREATURES THAT LIVE IN THE WATER

Citizens of the Water World. All living creatures need water inside their bodies. Many creatures, such as the fishes, need water outside their bodies as well as inside. The world of water is even more thickly inhabited than the worlds of air and rock. Scientists, as we have said, believed that life first appeared in the waters of the earth. Hordes of creatures, as all of us know, still live in the water.

The world of water is a world of interest and beauty

Dr. Roy L. Miner, A. M. N. H.

Most of us can easily reach some part of the world of water. Those of us who live near the seacoast can make a trip to the shore. Many of us live far from the sea but near some stream or lake. Those of us who live in large cities can go to a public park, where there is usually a pond or a pool of water. Wherever we live we can study some part of the world of water. We can have the thrill of discovering what a wonderful world it is.

We can become acquainted with its fascinating citizens. On the seashore we can study such creatures as starfish, clams, oysters, crabs, and sea urchins. In streams and lakes we can easily discover fishes, frogs, water bugs, snakes, and turtles. Each one is different from all the others in habit and appearance. All are endlessly interesting to the boy or girl who wants to know how the people of the water live.

There are many good books that will help you to name the creatures you discover and tell you about their lives. There are books on fishes and books on frogs, books on insects and books on plants. Your teacher will help you to find these books so that you may more easily get acquainted with the citizens of the water.

Go to the nearest seashore, stream, or lake, and study the creatures that live there. Keep a record of every interesting thing you see. Observe that not all water animals spend all their time in the water. Ducks, for example, live on the land part of the time. Frogs and mosquitoes live wholly in the water when young, and chiefly on the land when grown up. Do you know what young frogs and young mosquitoes look like? If not, ask your teacher to show you pictures of them.

Exercise. Make lists of the living things you observe in your studies of water life, as follows: (*a*) animals that spend

How many of these citizens of the world of water do you know?

all their lives in the water; (*b*) animals that spend about half their lives in water and about half on land; (*c*) animals that live on land but are frequently found near water; (*d*) plants that live wholly in the water; (*e*) plants that live on land but are usually found near water.

Use the name of each animal and plant if you know it. If not, use a brief description, like "a little long-legged gray bug that skates on the water."

Once you become interested in the people of the water, you may want to go again and again to observe their amusing ways. Many children have done so in the past. Many of these children are now grown men and women. They are still going to the world of water to learn its secrets.

Bringing the Water World into the Classroom. When winter comes it is hard to study the world of water outdoors. But we can bring a bit of it indoors and study it there. We can get a glass globe or tank and make a little water world of our own. We can put several different kinds of water plants and animals in the globe or tank, and watch them all winter long. In other words, we can make an *aquarium*.

Exercise. How to make an aquarium: Place an inch or more of coarse sand or gravel on the bottom of a watertight globe or tank. Get some water plants from a pond or a fish store. The tall grasslike *Vallisneria* is especially good because its leaves give off much oxygen in sunlight, and the oxygen will purify the water. Push the roots well into the sand. Add some floating water plants if possible. Fill the globe or tank with water to within an inch of the top. It should then be left for a week or more, so that air bubbles and other gases will have escaped.

Courtesy, Marineland

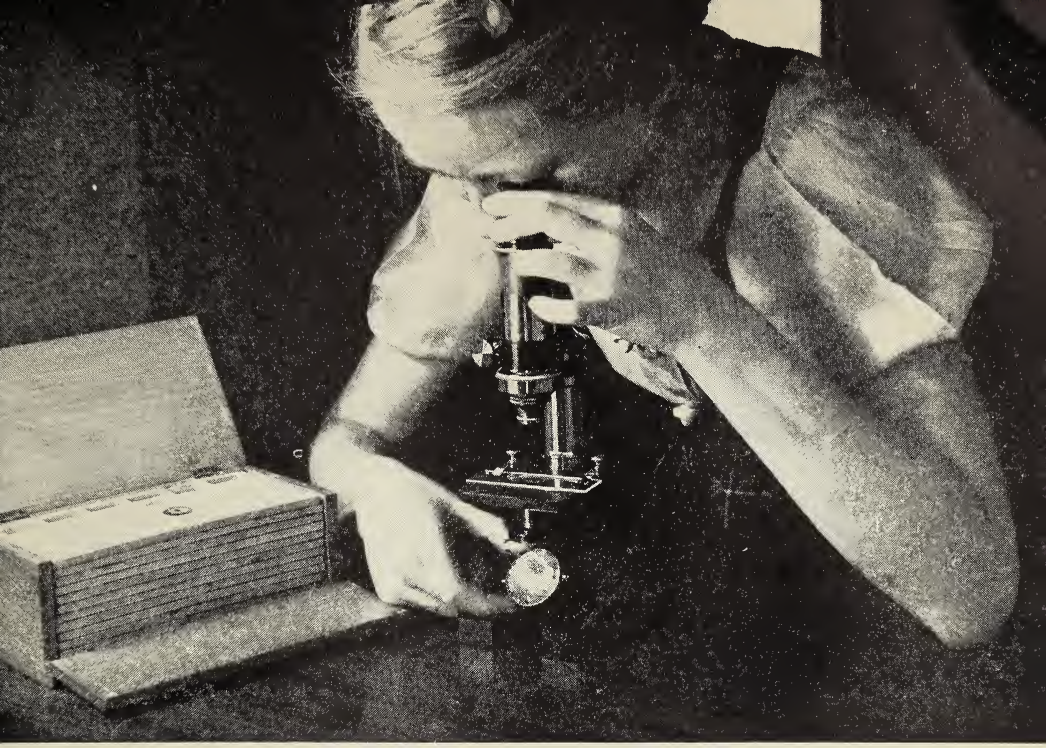
This man is feeding a porpoise in the great aquarium at Marineland, Florida. A mall aquarium that you could make for yourself would be less spectacular but just as much fun

Next add the animals. The kind and number you choose will depend on conditions. Sunfish, catfish, young eels, or minnows are good. Salamanders, snails, or tadpoles may have a place. Turtles and water beetles are not desirable because they are likely to eat or injure the fish. If salamanders are used, be sure the aquarium has a glass cover. Do not put too many animals in your aquarium!

There are several good books on how to make a well-balanced aquarium. Ask your teacher how you may find one of them. With its help you should easily be able to make a beautiful and successful aquarium. You should be able to match the conditions in nature so well that the water stays sweet and clean without changing, the inhabitants alive and well for any length of time.

Invisible Citizens of the Water World. Your observations have already shown you that the world of water is peopled by a numerous and varied society. Yet all the creatures you might see in a lifetime of such observations would not represent a very large percentage of the creatures that live in that world. By far the largest percentage of water-dwellers are invisible to the naked eye. They are so small that ten thousand of them might lie comfortably end to end in a single inch!

Up to less than three hundred years ago nobody suspected that this vast invisible society of water people existed. Then a wonderful instrument, called the *microscope*, was invented. "Microscope" means "a watcher of small things." It contains glass lenses which greatly enlarge, or *magnify*, the appearance of an object placed beneath them. Imagine the thrill of the first person to place what seemed to be a clear drop of water under the lenses



With the help of a microscope this girl is watching
the tiny creatures whose home is a drop of water

of a microscope and then to discover that it was a whole world in itself—swarming with life!

You need not merely imagine this thrill. You may experience it. You may make the invisible citizens of the water visible. Microscopes are common instruments in scientific laboratories today. There is probably one in your own science classroom. Go to it with enthusiasm and you will be amply rewarded. It is the window of a strange new world.

Exercise. How to breed microscopic creatures: Put some hay or grass in water, and leave it in a warm place for two or three days. Put a little cotton on a glass microscope slide. Take up some of the water with a medicine-dropper and squeeze two or three drops on the cotton.

Cover the cotton with another microscope slide and place it under a microscope. Focus the microscope and you will see several kinds of tiny living creatures.

Observe that the little citizens of the microscope world are not all the same shape. Some are shaped like a tiny slipper; others are nearly round. Some are lively; others are lazy. All of them take bits of food from the water. If you watch carefully, you may see them eating. You may see them eating one another, for many of them are cannibals. You may see them eating the remains of comrades that have died.

Exercises. Write brief descriptions of the different kinds of microscopic water creatures you have observed. If you have seen them feeding, describe what happened.

Prepare a slide containing a few drops of water from a roadside mud puddle. Are there microscopic creatures in this water? If so, how do they compare in number, shape, and habit with the creatures you studied in the preceding exercise?

Many of the creatures you have seen through the microscope consist of but a single living cell. Is it not wonderful that they should be able to eat, breathe, and move around with such simple bodies? With only one cell these tiny citizens of the water do many of the things that we do with the help of billions of cells. That they should be able to live at all is one of the wonders of nature.

HOW WATER CREATURES LIVE

Why Water Animals Die on the Land. Animals that live in the water all the time, such as fishes, lobsters, jellyfishes, and sponges, soon die if they are kept out of water. Why?

Microvivarium photo

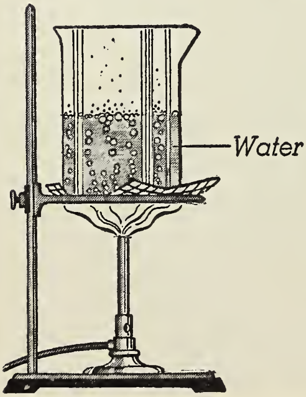
These boys are studying the microscopic citizens of the water world. They are looking at the moving images of actual creatures that are alive in a drop of water, enormously magnified and thrown upon a screen at the World's Fair in New York

Obviously they cannot move about very well on the land, and cannot find their food there. But they do not ordinarily die from starvation. They die from the much quicker process of suffocation. They die, in other words, because they cannot breathe out of water. They drown in the air just as land animals sometimes drown in the water.

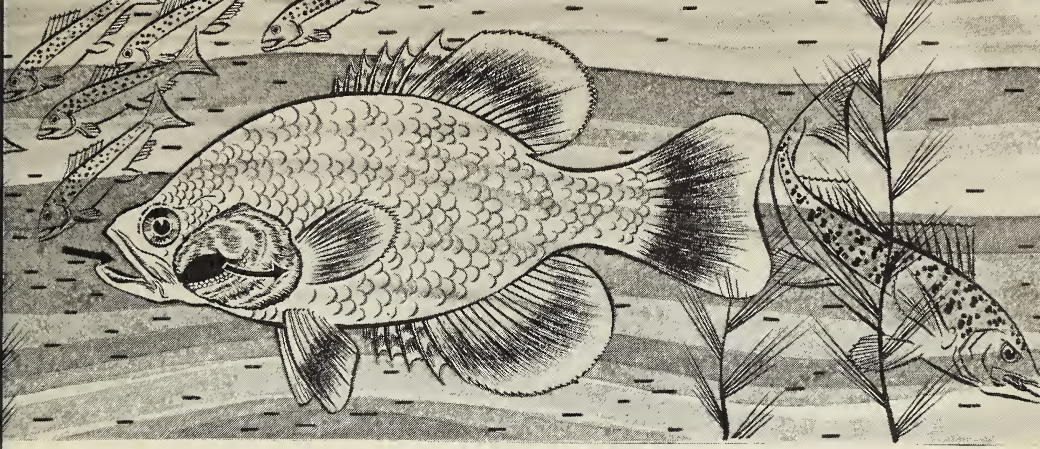
Oddly enough, both land and water animals breathe air. Neither can live without *oxygen*, a gas which is very abundant in air. *Water animals, however, cannot take oxygen out of the air until the air is dissolved in water.* That is why they die on land for want of oxygen, even though they are surrounded by it.

Exercises. How to prove that air is dissolved in water: Place a glass of fresh water in the sun or on top of a warm radiator. After a few minutes you will see bubbles clinging to the inside of the glass. These are air bubbles. Where did the air come from?

Heat some water over a flame as shown at the left. The bubbles that rise before the water begins to boil are bubbles of air. Where did this air come from?



How a Fish Breathes. A fish, like every other animal, must get oxygen or die. It must also, like every other animal, get rid of *carbon dioxide*, which is a harmful waste product. Like oxygen, carbon dioxide is an invisible gas. In all animals and in human beings, *breathing consists in rhythmic movements which bring oxygen into the body and push carbon dioxide out.* Many animals have



A fish breathes by taking water in at the mouth and passing it out through the gills

special organs for doing this important work. We do it with our *lungs*, which work beautifully on land but not at all under water. Fish do it with their *gills*, which work beautifully under water but not at all on land.

The drawing above shows a fish with its gills exposed. The arrows show how water constantly moves in at the mouth and out again through the gills. The gills are made of many tiny thin-walled blood vessels which are always full of blood. As the water passes through the gills, some of the oxygen dissolved in it seeps into the little blood vessels. At the same time carbon dioxide seeps out of the blood vessels into the water. In this way the blood of the fish is fed with the life-giving oxygen, and at the same time is freed from the carbon dioxide.

Exercise. Get a fish's head from a fish you have caught or from a fish market. Cut it open carefully so that you can see the gills. Notice how beautifully they are designed for straining the air from the water.

Plants of the Water World. Thus far we have been chiefly concerned with the animals that live in the world of water. There is also much plant life there. You know from observation that there are many water plants, such as seaweed, water lilies, pickerel weed, grasses, and sedges. These plants need light and air and water, just as land plants do. Soil is not so important for them because they get mineral salts from the water. They also get air from the water, as fishes do.

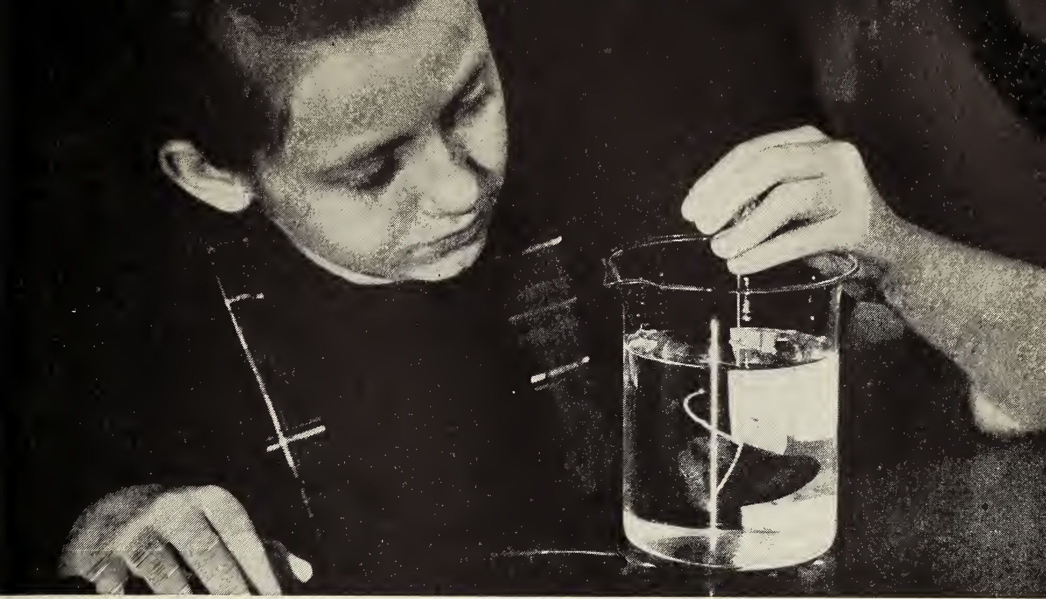
Water plants serve as food for water animals, just as land plants serve as food for land animals. Life in the water is really not so very different from life on land. The picture opposite page 68 shows some common forms of water life.

The Advantages of Living in the Water. There are, however, a few important differences between land and water life. In some ways life in the water is easier than life on land. For one thing, there is never any lack of water, as is often the case on land. A fish in water never suffers from thirst! Not only that, but water creatures do not have to stand any great differences of heat and cold, because changes in the water temperatures are always slow and relatively slight.

It is never so hot on hot days in the ocean as it is on land, nor so cold on cold days. Sea water is only a little warmer at noon than at night, and only a little colder in winter than in summer. Even the water in a pond grows warm more slowly than the land around it. On the hottest days of summer the pond is still cool enough to be a pleasant place for bathing.

In winter the temperature on land may be many degrees below the freezing point of water. Ice may form on the surface of lakes and rivers, but beneath the ice the water is generally not cold enough to freeze. Many plants and animals live comfortably enough beneath the ice.

Another advantage of life in the water is the support that water gives to the bodies of creatures that live there.



This girl is trying to discover the effect of water on the weight of a stone

We have all noticed how much lighter a stone seems to be when we lift it under water. This is because the water helps to hold it up.

Exercises. How to determine whether water helps to support the weight of an object: Fasten a string to a small stone and slowly lower it into a vessel of water, as shown in the photograph above. Does the stone seem to get lighter when it enters the water? Does the water support part of the weight of the stone?

Fasten a string to a block of wood and lower the wood into a vessel of water. How much of the weight of the wood is supported by the water?

In the same way plants and animals are supported by the water. Land trees must have strong trunks to hold up their branches, but water plants may—and usually do—have slender stems. Water lilies have very large leaves and flowers, as is shown on page 68. On land their stems cannot support the weight of either leaves or flowers, but the water holds them up so that the sunshine may reach them.

Water lilies have very weak stems. They could not live if the water did not lift their leaves and flowers to the sunlight.

Water animals, from the largest whale to the tiniest minnow, are supported in similar fashion by the water. Their bodies are not nearly the burden to themselves that the bodies of land animals are.

Our First Exploration. We now come to the end of our first exploration in the world of water. We have seen that all living things need water, animals no less than plants, land creatures no less than water creatures. We have answered the question "Is water necessary to life?" with an emphatic Yes.

We have also met some of the interesting citizens of the water and have learned something about how they live. But we have not yet learned very much about the water itself. Water is truly one of the most interesting things in the world. People are likely to take it for granted because it is so abundant. Scientists, however, take nothing for granted. They pry into everything to see what it is and how it works. By doing so they discover many interesting things which they never dreamed existed.

Let us, then, turn for a chapter from the creatures that use the water to the water itself. Let us see if we can discover what it is and what it does.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The world in which we live is divided into several worlds which have no relationship to one another.

2. An oasis is the driest part of a desert.

3. Plants that live in dry places have learned to get along without water.

4. Our bodies are made entirely of solid materials.

5. The kidneys work harder than any other organs in our bodies because they must do all the work of removing the water which has become filled with poisonous waste.

6. Very few living creatures spend all their time in the water.

7. The only way of keeping oxygen in the water of an aquarium is to change the water regularly.

8. When water animals die on land, it is because they cannot find their customary food.

9. The chief difference between a cat and a catfish is that the cat breathes air and the catfish water.

10. The gills of a fish are wonderful organs for straining food from the water.

11. Water plants are beautifully fitted for living without air or light.

12. Life is difficult in water because conditions are much more changeable there than on land.

13. Water creatures must not only support their own weight but also the weight of the water that lies on top of them.

14. Whales are so heavy that they can hardly bring themselves to the surface of the sea.

Questions for Discussion

1. Why are camels used as beasts of burden in desert regions?

2. Many common words have a much deeper meaning to the person who knows science than they do to those not so trained. For example, the word *thirsty* means much more to the scientist than it does to other people. After reading this chapter, what does this word mean to you?

3. Why is water so necessary to the life of the cells in the body?

4. People have been known to die from painting their bodies from head to foot. Why should painting the body cause serious illness or death?

Things to Do

1. Obtain or make an outline map of the world. Locate all the large deserts and color in these areas with crayon. Find out the average annual rainfall in each of these desert regions and place this information on the map.

2. If you like to draw and paint, here are some suggestions you may want to try out:

a. Paint a scene to represent an oasis in a desert. Before you begin, find out what kinds of plants, animals, and people one might expect to see there.

b. Make a sketch to show a caravan moving across the desert.

c. Sketch a scene to show typical pond life.

3. Keep a record of the amount of water you drink each day for a week. This, of course, will not include the water in the foods you eat, such as fruit, vegetables, and milk. You might estimate the amount of water in your food and add to the record.

4. Have you ever wondered how it would feel to live in the water? Kingsley's *Water Babies* is the make-believe story of children who became water fairies. You may want to read this.

5. Read Beebe's *Beneath Tropic Seas* or *Nonsuch: Land of Water.* The pictures of ocean life in either book are excellent.

CHAPTER FOUR

What Is Water?

WATER IS A LIQUID

Water is a Wizard. We have all read stories about wizards who could change themselves into plants, animals, or stones. We call such stories fairy tales; we know they are untrue. There is no proof that a human being has ever been able to do such a thing. There is a different sort of wizard, however, that really can change from one form to another. Indeed, we have all seen this wizard do it. The wizard is water.

Why Is Water Wet? We generally think of water in only one of its forms. We think of it as the thing we drink, the thing we see in running streams and in wave-tossed lakes and oceans. How shall we describe this common form of water?

In the first place, water in this form is clear. We can look right through it. But we can also look through glass, and glass is certainly not water. "What is the difference between water and glass?" we ask ourselves. This seems a silly question, and we are irritated with ourselves for not being able to answer it at once. We think we *know* the difference between water and glass, but it is not so easy to *say* what the difference is. Suddenly we have an idea. How stupid not to have thought of it right away! "Water is wet," we say to ourselves, "and glass is not. That is the chief difference between them."

We are quite satisfied with this answer for a few moments—but only for a few moments. "But what," we ask ourselves, “does ‘wet’ mean?” We try to think of what we mean when we say a thing is wet. When we are out in the rain without an umbrella, we get wet. When we put clothes to soak in water, they get wet. Getting wet, we decide, merely means getting soaked with water. “A pretty circle!” we exclaim. “Water means being wet, and being wet means soaked in water.” We have got nowhere.

Water Has No Definite Shape. Not discouraged, however, we go on with our thinking. Why does water wet our clothes when many other things do not? If we are out in a hailstorm, the hail does not wet us so long as it does not melt. It bounces off our backs. When we sit on the dry sand of the shore or on the hay in a barn, our clothes do not get wet. A little sand or hay may stick to us, but we can easily brush it off. When we go in swimming, however, our bathing suits stay soaked with water. We cannot brush off the water as we brush off sand or hay.

“What,” we ask, “is the difference between water on the one hand and hail, sand, and hay on the other? Why does water ‘wet’ us when hail, sand, and hay do not?” With this question we suddenly come to the end of the puzzle. “Of course,” we say; “why didn’t we think of it before?

“Hail, sand, and hay are stiff. They either bounce off or cling to our clothes without soaking all through them, because they are so stiff. They hold their shape. Water,

Sand can be brushed off clothing, but water cannot. Do you know why?

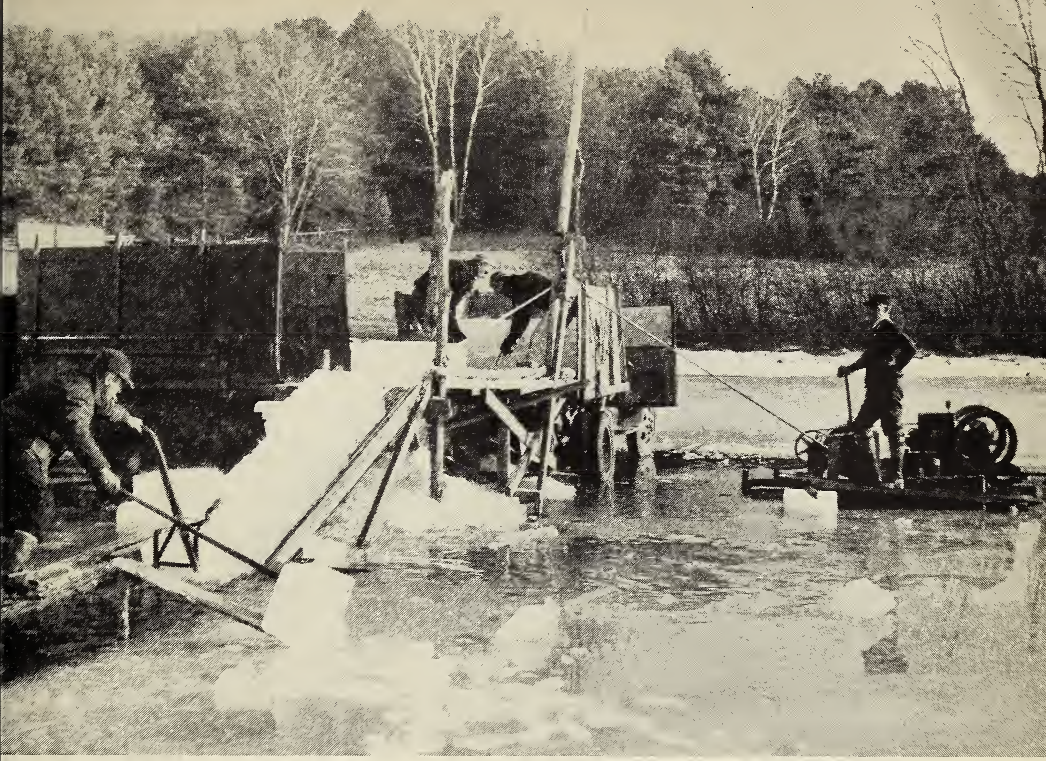
on the other hand, does not hold its shape. It soaks into every nook and cranny of our clothes and makes them wet because it can take any shape."

Water Has a Definite Size. The fact that water has no definite shape is the first thing we must know if we are to understand it in its commonest form. The second thing we must know is that *it does have a definite size.* The size of anything is often referred to as its *volume*, and is measured by cubic units. Thus the volume of a box which is 3 inches long on each side is 27 cubic inches.

Exercise. How to prove that water has a definite size, or volume: Fill a drinking glass with water. What is the shape of the water? How deep is it? Pour the water into a large flat dish. What is the shape of the water now? How deep is it now? Pour the water back into the drinking glass, being careful not to spill any, and not to leave any in the dish. What is the shape of the water now? Is there considerably more or less water in the drinking glass now than at the beginning of the experiment? Has the size (volume) of the water changed in the course of the experiment?

From this simple experiment you can see that changing the shape of water has no effect on the size. With this observation we come to an important conclusion about water in its commonest form. *Its shape varies with the shape of the vessel that holds it, but its volume remains the same.* Anything that behaves in this fashion is called a *liquid.*

Exercise. Name as many common liquids as you can. Does their volume change when their shape is changed?



Wide World

Ice is solid water

WATER IS A SOLID

Ice. We all know that water does not always stay in liquid form. Many of us have observed that the water in shallow puddles turns stiff during cold weather. Some of us have observed that the same thing happens to rivers in winter. All have observed "stiff" water in our drinks at the soda fountain. We all know that such water is called *ice*.

What Solids Are. What is the chief difference between water in its liquid form and water in the form of ice? This is an easy question. We really answered it before we asked it, when we said that ice is "stiff" water. *When water gets cold enough it freezes, which means that it gets the ability to hold a definite shape as well as a definite volume.*

Frozen water, or ice, shares with the sand and hay of our earlier observation this ability to hold its shape and volume. Many other things have the same ability. Such things are known as *solids.*

Exercise. Name half a dozen solids which you see every day.

How Cold Is Water When It Freezes? We all know that water does not freeze into ice unless it becomes very cold. But how cold must it become? Does it freeze at a definite or at an indefinite degree of coldness?

We can answer these questions through an experiment with the help of that common but none the less clever instrument, the *thermometer.* "Thermometer" means "a measurer of heat." This instrument is also "a measurer of cold," because cold is merely the absence of heat.

What a Thermometer Is. In measuring heat and cold, thermometers make use of certain facts which people learned long ago through scientific observation. It has long been known that *most things get larger (expand) when heated and smaller (contract) when cooled.* It has also been known for a long time that *the volume of certain things is much more greatly changed by heating and cooling than is the volume of certain other things.* The liquid called mercury, for example, is much more sensitive to heating and cooling than is the solid called glass.

The commonest kind of thermometer is merely a hollow tube of glass which has been partly filled with mercury and sealed. When heated or cooled, the mercury climbs up or down in the tube because it expands and contracts much more than does the glass. By putting little numbered marks on the glass, the amount of change in the volume of the column of mercury can be accurately observed.

SALT

Degrees. The little numbered marks on the glass of thermometers are known as degrees. When the mercury is heated or cooled, it moves from one numbered degree to another. This movement measures the change in heat, or *temperature*, around the outside of the glass. The degree is therefore not merely an accurate measure of the distance the mercury has moved. It is an accurate measure of the change in temperature which has caused the movement.

The Freezing Point of Water. Armed with a thermometer, we are ready to seek the answer to the question How cold is water when it freezes?

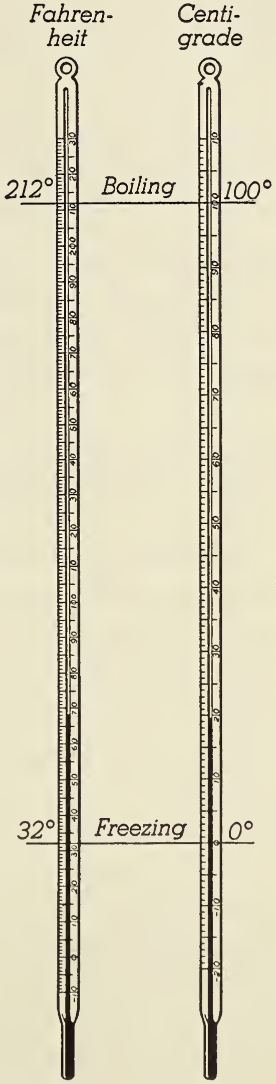
Exercise. How to determine the temperature at which water freezes: Obtain a thermometer, a test tube half filled with water, a cup, about a pint of cracked ice, and several tablespoonfuls of salt. Mix two or three tablespoonfuls of salt with a cupful of ice. Place the thermometer in the water of the test tube, the test tube in the cup of ice, as shown in the photograph on page 77. Pack the ice and salt very firmly round the bottom of the test tube. Keep adding new salted ice to the cup as the old ice melts, until ice begins to form in the test tube.

What happens to the mercury before the water begins to freeze? What happens to it after freezing has begun? At what degree of temperature does freezing take place?

The temperature at which the water changes from a liquid to a solid is known as its freezing point. Under ordinary conditions the freezing point of fresh water is always the same the world around.

As long as the temperature remains at or below the freezing point, water remains solid. When the temperature rises above the freezing point, the water turns back to the liquid form. The ice, as we say, *melts.*

Fahrenheit and Centigrade. Though the temperature at which fresh water freezes does not vary under ordinary conditions, the way we speak of this temperature varies with the style of thermometer used. In other words, the degrees are marked and numbered differently in different styles of thermometers. They stand for different temperatures.



The commonest style of thermometer is called the *Fahrenheit thermometer*, after the German scientist who invented it. On this thermometer the freezing point of fresh water is at 32 degrees (32°). The boiling point of fresh water, as we shall prove later by an experiment, is as definite a temperature as the freezing point. On the Fahrenheit thermometer the boiling point is marked 212 degrees (212°). Between the freezing and boiling points of water there are, accordingly, 180 degrees (180°) on the Fahrenheit scale.

The *centigrade thermometer* is used chiefly by scientists. "Centigrade" means "consisting of one hundred steps." It refers to the division of the scale of this thermometer into 100 steps, or degrees, between the freezing and boiling points of fresh water. The freezing point is marked 0° and the boiling point 100°.

You will often see the letters F. and C. after temperature readings, to show what kind of thermometer was used. Thus, 60° F. refers to a reading on a Fahrenheit thermometer and 60° C. to a reading on a centigrade thermometer.

The picture on page 79 shows Fahrenheit and centigrade thermometers of the same size side by side. Notice that although marked differently, *the boiling and the freezing points are at the same levels in both thermometers.* They are at the same levels because the temperatures at which fresh water boils and freezes do not vary no matter how a thermometer is marked.

Exercises. Does a degree on the Fahrenheit thermometer represent a greater or a lesser range of temperature than a degree on the centigrade thermometer?

What is 40° Fahrenheit on the centigrade scale? 60°? 100°?

How many degrees on the Fahrenheit scale make one degree on the centigrade scale?

What Salt Does to the Freezing Point of Water. In the experiment with the thermometer we used a mixture of salt and ice because the temperature of such a mixture is lower than the freezing temperature of fresh water. By packing the test tube in salted ice we surrounded it with a temperature that was lower than the freezing point of the water it contained. In this way we speeded up the formation of ice in the test tube.

Water with salt in it freezes at a lower temperature than water without any salt. In other words, it must be colder to freeze salt water than fresh water. If you have been to the ocean in fall or winter, you may have observed that this is so. Ocean water, even when trapped in small inlets, may contain no ice though fresh-water ponds near by are covered with ice. Ocean water, as you know, has salt in it. If we were to set our thermometer in a tube of ocean water and pack ice and salt about the tube, we should find that it does not freeze at 0° C. (or 32° F.), as fresh water does. Ocean water freezes at about 1.9° C. *below* zero. Temperatures below zero are written with a minus sign. Thus the temperature at which ocean water freezes is written −1.9° C.

What Happens to the Volume of Water When It Freezes. When water becomes ice, it not only becomes stiff; it also becomes larger. In doing so it shows itself to be a freak in nature. Most things get smaller when they change from the liquid to the solid state. When water is first cooled, it starts to behave like other things. It shrinks. But just before it freezes solid, it expands. It becomes about one tenth larger than it was before it was frozen.

What Happens to the Weight of Water When It Freezes. Because of this expansion, ice is a little lighter than water in amounts that are the same. That is why ice forms on the top of water first. That is why it floats. This is very fortunate for the creatures that live in streams and ponds. If ice were heavier than water, it would sink to the bottom of lakes and ponds and kill every creature there. Instead, it forms and stays at the top, and allows the creatures underneath to go through the winter safely. Only in extremely severe winters do streams and ponds freeze all the way to the bottom.

Man's Battle with Ice. Ice is often an obstacle to men. Before the days of the airplane, arctic explorers knew only too well how great an obstacle ice can be. Imagine traveling over an icy waste, as the man in the picture on page 82

Galloway

Pack ice and speedy travel just do not go together

is doing! You might decide that the north pole was not worth the trouble, and no one could fairly blame you. Unfortunately we can know how troublesome ice can be without being arctic explorers. You have probably already experienced the unpleasantness and danger of ice on an automobile highway.

Most damage is done by ice when it forms in a closed container like a pipe or the radiator of a car. The push of water as it enlarges into ice is truly terrific. *It expands with a pressure of over two thousand pounds on every square inch of the container.* No wonder pipes and radiators burst when the water inside them freezes! No wonder great cliffs are shattered when water freezes in the cracks between the rocks.

Fortunately men have discovered ways of fighting this power of freezing water. Certain liquids freeze at much lower temperatures than the freezing point of water. In many cases these liquids can be mixed with water, and the mixture will not freeze as readily as water alone.

When winter approaches, the garage man may remind your father to put some "antifreeze" liquid in the radiator of the automobile. Alcohol is one common "antifreeze" liquid. You let some water run out of the radiator, put in four or five quarts of alcohol, and finish filling the radiator with water. Now you are prepared for very cold weather. Alcohol in water acts like salt in water. It lowers the freezing point and thus reduces the danger of expansion, which would burst the radiator.

WATER IS A GAS

The Boiling Point of Water. The wizardry of water does not stop with its ability to change from the liquid to the solid form. There is yet another form which it can, and frequently does, take. This form is just the opposite of the solid form. It is produced in a way that is just the opposite of the way in which ice is produced.

Exercise. How to find the boiling point of water: Put exactly one pint of cold water in a vessel. Hang a thermometer in the water, as the children in the picture on page 84 have done. Do not let the thermometer touch the bottom. Read the thermometer; then heat the vessel over a flame. What does the mercury do as the water gets hot? What does it do after the water begins to boil? Allow the water to boil for five minutes and observe whether its temperature changes during the boiling. Turn off the heat. When the water is sufficiently cool, measure its amount. Is there more or less water now than when you began the experiment?

These children are finding the boiling point of water

This simple experiment will give you definite proof for the statement made earlier in this chapter about the boiling point of water. It will show you that the boiling point is as definite a temperature as the freezing point. At sea level fresh water in an open vessel will boil at 212° F. or 100° C. No amount of boiling and no additional amount of heat under the vessel will make the water any hotter.

Evaporation. You may be puzzled by the fact that after boiling has begun, heat no longer raises the temperature of water. Is this heat wasted? Does it accomplish nothing?

The answer to these questions lies in an observation which we have all made many times. When water boils, some of it turns into steam. The water that was lost in the course of the last experiment went into the air as steam. More steam is given off by vigorously boiling water than by gently boiling water. Though no amount of heat can raise the temperature of liquid water above its boiling point, the greater the heat the greater is the amount of steam produced in a given time.

Water in the form of steam is known as *water vapor. The process whereby liquid water is turned into water vapor is called evaporation.*

What Gases Are. Water vapor is a gas. To know what a gas is we need only know the difference between water in the form of water vapor and water in its other forms. But what exactly is the difference? The answer lies in a few simple observations on steam.

In the first place, we have all observed that steam rises. If it were heavier than water, it would sink below the surface of the water. Instead it not only rises to the surface, but it leaves the surface and wanders into the air. This can mean only one thing. Water as a gas is not only lighter than an equal volume of water as a liquid, but it is also lighter than an equal volume of air.

Once in the air the water vapor shows its true nature as a gas. It curls and writhes as it rises. It shows itself unable to hold either a definite volume or a definite shape. *Anything without the ability to hold a definite volume or a definite shape is called a gas.*

Exercise. Name as many gases as you can.

The Three Forms of Water. We have now arrived at part of the answer to the question, "What is water?" We can say that water is a thing that can take the form of a liquid, a solid, or a gas. We can define these forms as follows:

A liquid can hold its volume but not its shape.
A solid can hold both volume and shape.
A gas can hold neither volume nor shape.

Here is proof that there is water in the air. Do you know how it gets there?

THE WATER CYCLE

How Does Rain Get into the Sky? At one time or another you have probably been drenched by rain. Perhaps you started on a hike on a morning when the sun was bright and the sky cloudless. Happy in the prospect of a perfect day, you never dreamed that you might need the raincoat that was hanging in a closet at home.

But after you had walked for an hour or so and were far from any shelter, you noticed that clouds were piling up in the sky. In a little while the sun was covered; the clouds were everywhere. Soon a few raindrops fell as if in warning, and then it poured. Your clothing was soaked in a moment. Little brooks began to flow in ditches that had been dry only a short time before. The long grass by the roadside was flattened by the falling water. The rain drummed on the leafy branches of the trees.

Such a common experience is proof of the fact that *there is water in the air.* The rain came out of the air. It must have been in the air before the storm, even though you could not see it. How did it get there?

Evaporation in the World around Us. We all know that water remaining on the pavement after a rain soon disappears when the sun comes out. The mud puddle by the roadside dries up in a few hours. We also know that water left in a pan soon disappears. Wet clothes hung on the line dry quickly in the sun or wind. What happens to all this water? Many of us know that the water on the pavement, in the mud puddle, in the pan, and in the wet clothes escapes into the air. It escapes exactly as the boiling water in our experiment escaped,—by evaporation.

The *speed* of evaporation depends on the temperature of the water. Evaporation takes place fastest from the surface of boiling water. Outdoors it takes place faster on hot sunny days than on cold dark days; faster in the daytime and in summer than during the night and during winter.

The *amount* of water evaporated depends on the amount of water surface that is exposed to the air. There is more evaporation in a given time from a large puddle than from a small puddle, even though the smaller puddle is deeper. *But fast or slow, much or little, evaporation is always going on wherever there is water in liquid form.* It is the water which has evaporated into the air that falls back to earth as rain.

Exercises. How to find out the effect of temperature on the speed of evaporation: Place exactly two spoonfuls of water in each of two similar dishes. Put one dish on a

Galloway

Notice the cloud of spray above the wave. This is one way that water vapor enters the air

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warm radiator and the other in the refrigerator or some other cool place. Observe them after one day and after two days. Does warm water evaporate more or less rapidly than cold water?

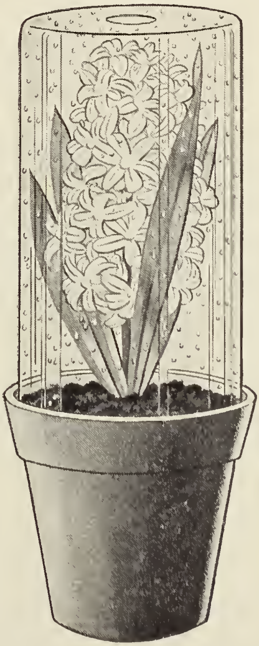
How to find out how the amount of water surface exposed to the air influences the amount of evaporation: Choose three vessels,—one flat and shallow like a cereal dish, the second tall like an olive bottle, the third an ordinary drinking glass. Put exactly two tablespoonfuls of water in each of the three vessels and place them on the window sill. Observe them each day for a few days. Which dish goes dry first, which next, and which last? Does the amount of water surface exposed to the air influence the speed of evaporation?

The above experiments, though performed inside a building, will show you some of the chief conditions that control the speed and amount of evaporation in the world in general.

How can enough water evaporate from the surface of the earth to make so many and such heavy rains? The picture on page 88 will help you to answer this question. Evaporation is going on all the time over all the oceans, over all the lakes and rivers, from moist soil, and from the leaves of plants. These vast and varied sources of water vapor are quite able to produce all the rain that falls the world around.

Plants as Rain-makers. The cells in the stems of plants—corn, wheat, or trees, for example—are so arranged that water can pass with ease from roots to leaves. The cells of a healthy plant are always wet. Water continuously enters the roots from the soil, and continuously escapes by evaporation from the undersurfaces of the leaves.

The stream of water that flows through the body of a plant is in some ways like the stream of blood that flows through the body of an animal. It carries food in and waste out. By a simple observation you can prove that a large amount of water enters the air from plants.



Exercise. How to prove that plants give water to the air: Place a large jar over a healthy potted plant. Use a plant that has not been watered for twenty-four hours. After a time, perhaps an hour, the inside of the jar will appear wet, as in the drawing at the right. Where did this moisture come from? To prove that it did not come from the air, place a jar over a pot of soil that does not contain a plant. Does this jar get wet? Where, then, did the moisture in the first jar come from?

You may be surprised to learn how much water evaporates from plants. Careful observation has shown that one acre of meadow grass in one season gives to the air more than five hundred tons of water! Think of the millions of square miles of the earth's surface which are covered with vegetation, and you will realize that a great deal of moisture reaches the air from plants. One large tree alone gives off several tons of water in a single summer. Since this moisture may later return to the earth as rain, you can see that plants are very effective rain-makers.

How Rain Is Made. Should you like to know how water leaves the air? One way is by the formation of clouds. You have learned that water changes from liquid to gas when heated. You might expect, then, that the water vapor would change back to liquid when cooled. That, indeed, is what happens.

When water vapor is cooled, it gathers in droplets around little particles of dust that are always floating in the air. The droplets grow larger and heavier until they can float no longer. They then fall to the earth as rain.

If the temperature of the air is at or below the freezing point of water, the droplets will fall as snow. We usually say that rain or snow falls from the clouds. We should be more accurate if we said that when it rains or snows, the clouds fall.

If You Were a Tiny Particle of Water. If you were a tiny particle of water, many things might possibly happen to you. One thing would surely happen. You would travel.

THE WATER CYCLE

Imagine yourself a tiny particle of water in the ocean. With countless billions of companions you are being rolled and tossed by the wind. You find it good fun to be moving about without getting anywhere in particular. Presently, however, you feel that you are getting somewhere. You feel yourself carried along by something more steady than the wind, something much more like a river. You decide that you are in an ocean current.

Now you are rising to the surface of the water with the movement of the current. You see the fishes swimming by, and from time to time they slap you with their tails. As you rise and rise you feel yourself getting much warmer. Finally, near the sunlit surface of the sea you begin to feel strangely active. Before you know it you are rising into the air! You are now a tiny particle of water vapor high in the sky.

hink of the billions of tons of water that are given to the air by the trees in this vast jungle wilderness

Hamilton Rice Expedition

In time it grows cold and misty. You feel yourself joining other particles of vapor and clinging to a bit of dust that drifts your way. You decide that you are in a cloud. Presently you feel yourself growing larger and heavier, and after a time you feel yourself falling. You cling to the dust, wondering what will happen next.

Before you can imagine what dreadful things might happen, you hit the ground. You discover that you have been shaken loose from the particle of dust. You are being carried headlong by billions of other water particles, and bumped by sand and pebbles much larger than yourself. You are being carried down the side of a hill in a tiny but fast-moving brook.

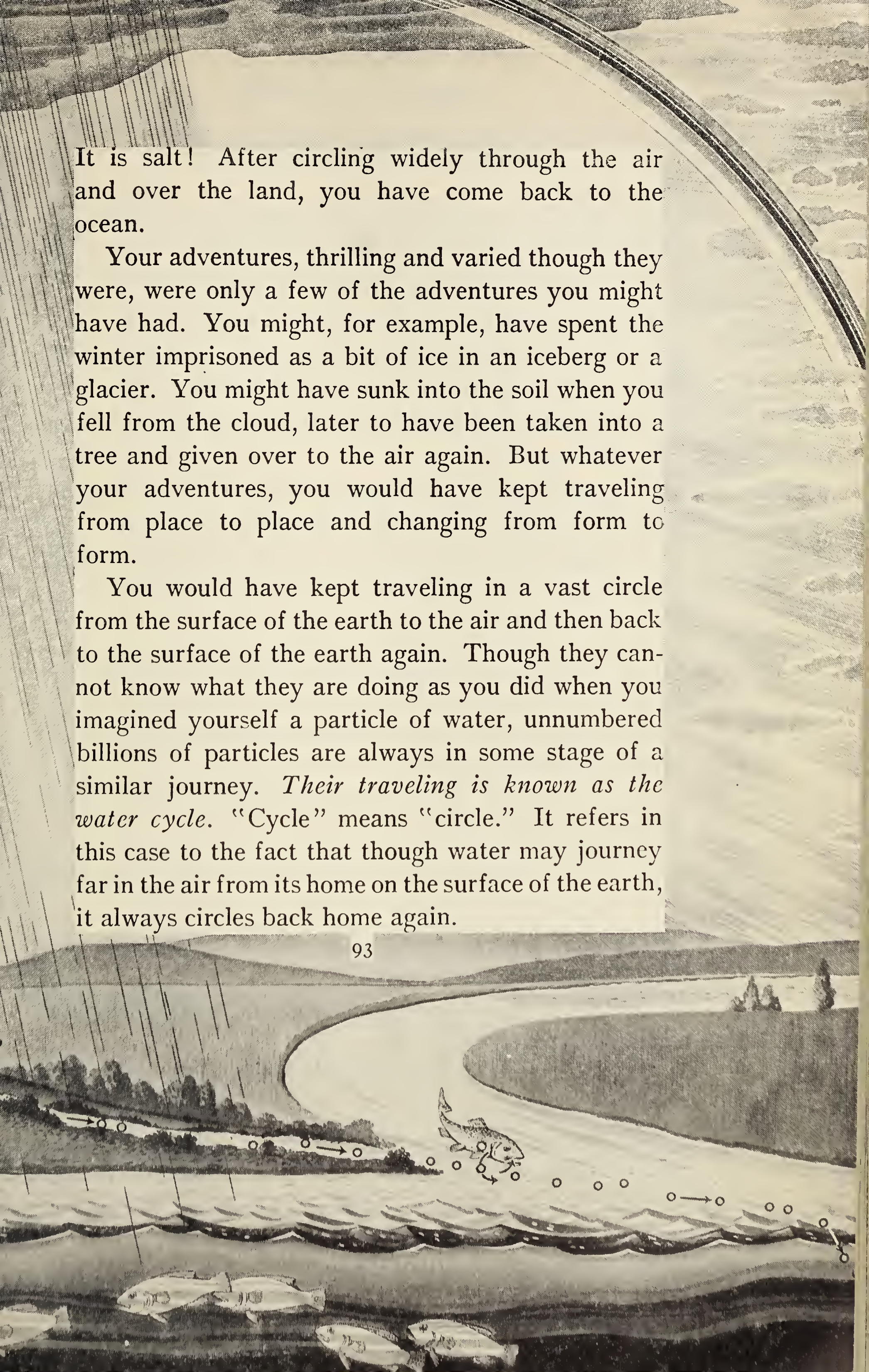
The hours pass and you realize that you are now moving more slowly and gently. The brook has joined a river. Down, down you drift, now rubbing the shore, now lazily wandering toward the middle of the river. Once a fish swallows you, but before you can be frightened you come out through his gills and go sailing merrily on.

Then suddenly one day you feel yourself slow down. You taste something which seems familiar.

It is salt! After circling widely through the air and over the land, you have come back to the ocean.

Your adventures, thrilling and varied though they were, were only a few of the adventures you might have had. You might, for example, have spent the winter imprisoned as a bit of ice in an iceberg or a glacier. You might have sunk into the soil when you fell from the cloud, later to have been taken into a tree and given over to the air again. But whatever your adventures, you would have kept traveling from place to place and changing from form to form.

You would have kept traveling in a vast circle from the surface of the earth to the air and then back to the surface of the earth again. Though they cannot know what they are doing as you did when you imagined yourself a particle of water, unnumbered billions of particles are always in some stage of a similar journey. *Their traveling is known as the water cycle.* "Cycle" means "circle." It refers in this case to the fact that though water may journey far in the air from its home on the surface of the earth, it always circles back home again.



Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. A liquid can change in size but not in shape.

2. A solid can change in shape but not in size.

3. The centigrade thermometer has 180 degrees between the boiling and freezing points of water.

4. The freezing point of water is at 0° on the Fahrenheit thermometer.

5. Salt water freezes more easily than fresh water because salt raises the freezing temperature of water.

6. When water freezes it becomes one-tenth smaller than it was as a liquid.

7. Ice is only a little heavier than water.

8. Though the freezing point of water is a definite temperature under ordinary conditions, the boiling point is not.

9. Continuous boiling raises the temperature of water after boiling has begun.

10. Evaporation is the process whereby water vapor is turned into liquid water.

11. Water vapor is somewhat heavier than liquid water.

12. A gas cannot change in either size or shape.

13. More water evaporates in a given time from cool water than from warm water.

14. Water evaporates more rapidly from a drinking glass than from a cereal dish.

15. The leaves of plants draw a great deal of water from the air.

16. The term "water cycle" refers to the circular movement of water in clouds.

Questions for Discussion

1. Should you expect the temperature of steam as it escapes from the surface of boiling water to be higher or lower than the temperature of the water? Why?

2. Can you see any relation between plant life and the freezing point of water? Have you heard of a "killing frost"? Why should frost kill?

3. The soil often becomes very dry after a week or more of fair weather. Why?

4. It is possible that some of the water which is now in your body was once in the body of some other person, or even in some wild animal in another part of the world. Can you explain how this could be true?

Things to Do

1. Look up in a good encyclopedia the freezing points and boiling points of mercury, alcohol, and gasoline. How do they compare with water in this respect?

2. One of the worst tragedies in history was caused by ice. Look up the story of the steamship *Titanic* and see how it happened.

3. The United States government has a coast-guard patrol which cruises the northern steamship lanes on the lookout for icebergs. See if you can find some books telling about their work and how the icebergs are destroyed when they are found. This might make a good subject to report to your class.

4. Dissolve a large amount of salt in a pint of water and find the boiling point. How does it compare with the boiling point of fresh water?

5. Make a poster-diagram of the water cycle. Indicate the path of the water by colored arrows. Label carefully each stage of the cycle.

6. Start a "water scrapbook" and place in it pictures and news clippings from magazines and newspapers. Include such topics as water supply, droughts, water power, uses of water, and water transportation. This will make a good introduction to the material of the next two chapters.

CHAPTER FIVE

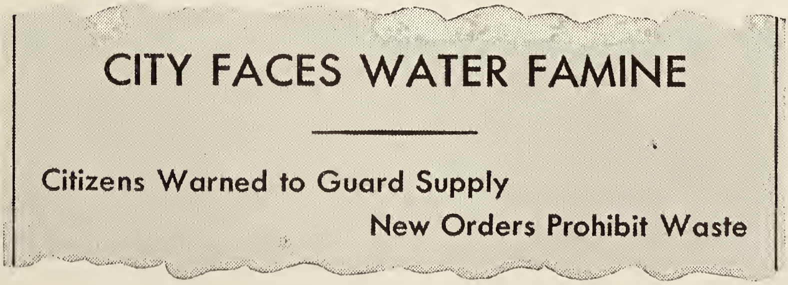
How Do We Get the Water We Need?

WATER IN YOUR COMMUNITY

Our Water Problem. We have explored the world of water. We have studied both the inhabitants and the water itself. Along the way we have seen something of the great need for water in our daily lives. How do we satisfy this need?

Every community has a water problem. In general, the problem is the same for all communities. *There must be enough good water for every citizen every day.* After this important problem is solved, we are likely to forget that it ever existed. Sometimes, however, it comes forcibly to our attention.

When the Water Supply Fails. "Did you see the headlines in this morning's paper?" John asked one morning as he came into the science room. "No. What do they say?" asked several of the boys. John began to read:

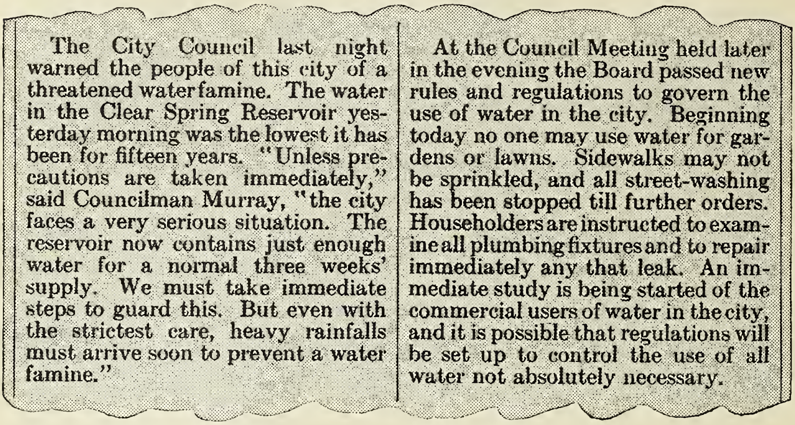


CITY FACES WATER FAMINE

Citizens Warned to Guard Supply

New Orders Prohibit Waste

Other boys stopped talking and turned to John. "Say, that may be serious," said one of them. "Read the whole article, will you?" John continued his reading:

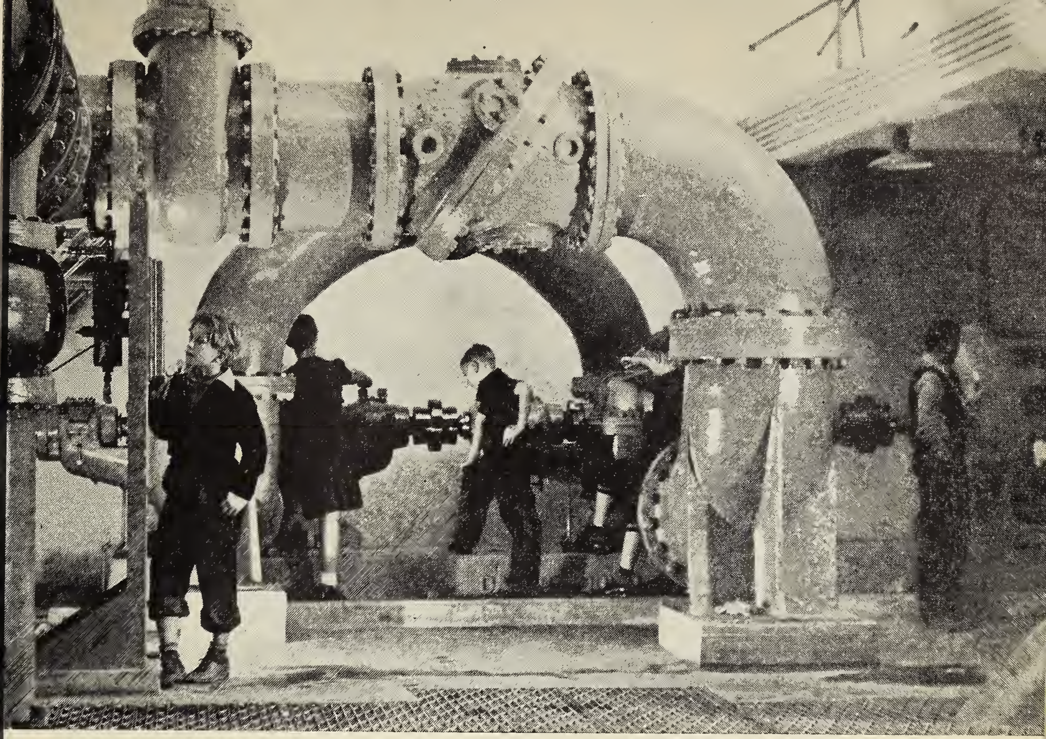


The City Council last night warned the people of this city of a threatened water famine. The water in the Clear Spring Reservoir yesterday morning was the lowest it has been for fifteen years. "Unless precautions are taken immediately," said Councilman Murray, "the city faces a very serious situation. The reservoir now contains just enough water for a normal three weeks' supply. We must take immediate steps to guard this. But even with the strictest care, heavy rainfalls must arrive soon to prevent a water famine."

At the Council Meeting held later in the evening the Board passed new rules and regulations to govern the use of water in the city. Beginning today no one may use water for gardens or lawns. Sidewalks may not be sprinkled, and all street-washing has been stopped till further orders. Householders are instructed to examine all plumbing fixtures and to repair immediately any that leak. An immediate study is being started of the commercial users of water in the city, and it is possible that regulations will be set up to control the use of all water not absolutely necessary.

The boys looked at one another. "That shows how much I know about my own city," said George. "I've never even

Does your community have a reservoir such as this? If so, where does the water come from and where does it go?



hese children are examining the pumps and large pipes that bring water into their city

thought about our water supply. To be perfectly honest, I don't even know where the reservoir is, except that it's somewhere on the Clear Spring Road. All I've ever known about our water is that you turn a faucet and the water is there. The idea never occurred to me that there might not be enough. But," he added, "I'm going to find out about it now."

Studying the Local Water Supply. Fortunately for Smithtown, heavy rains arrived the following week. A water famine was avoided, at least for a time. But the boys had become interested in the problem of water supply. They spent a great deal of time making trips and writing letters. They reported on where their local water comes from, how it is protected, and how it is brought to the city. They drew pictures and diagrams explaining the sources of the water

These boys are making a diagram of what they learned about the water supply of their community

and the means of purifying it. Before they finished, they had a complete story of their local water supply. They gathered all this together in the form of a class booklet called "Facts about Smithtown's Water Supply."

Exercise. What do you know about the water supply for your community? Where does it come from? How does it reach you? Who is in charge of it? Is there ever any danger of a water shortage in your community?

THE MUDDY IMPURITIES IN WATER

Pure Water and Good Water. Our water problem is really several problems. Getting *enough* water for our needs is only one of these problems. Getting *good* water is another. In many places getting good water is a more difficult problem than getting enough water.

THE MUDDY IMPURITIES IN WATER

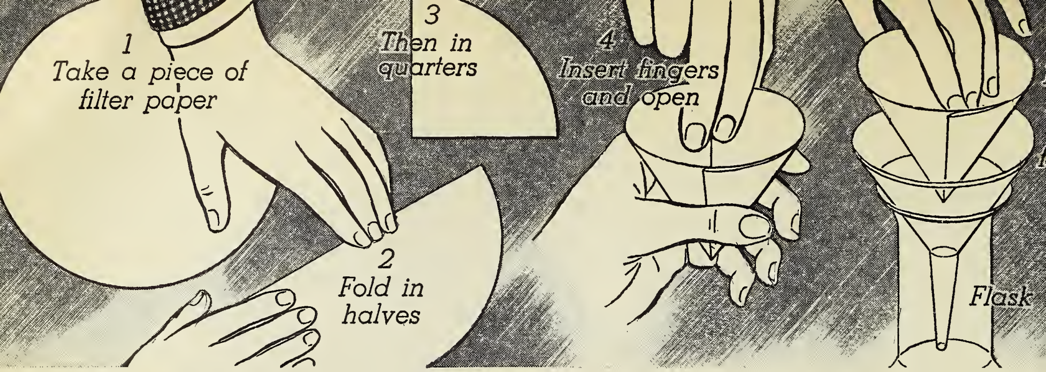
Water as it drops from the clouds is a clear and colorless liquid. It contains no mud or filth of any sort. We call such water pure. *Pure water is merely water which contains nothing that is not water.*

Is pure water good water? The answer to this question may surprise you. Absolutely pure water is good for some purposes, but it is not the best water for all purposes. It is good for washing clothes because it makes soap lather quickly and abundantly. It is good for the storage batteries of our automobiles because it does not contain any materials that might harm them. But it is not good for regular use as a drink.

Have you ever tasted rain water as it falls from the sky? We might better have asked if you have ever *drunk* rain water, because it has no taste. It is "flat," as we say, like food that has not been properly seasoned. What is it that makes rain water an unpleasant drink?

Most of the rain that does not fall directly into the oceans either flows over the lands in streams or sinks into the soil. This water acts as if it were hungry for the earth, because it picks up tiny particles of earth wherever it goes. We speak of these earthy particles as *mineral matter. The mineral matter in water is an impurity because it adds to water something that is not water.*

It is the presence of mineral matter that gives water its taste. Without mineral matter, rain water is naturally tasteless. Scientists have discovered that certain mineral impurities not only make water taste good but are necessary for our health. There are places, for example, where the absence of the mineral iodine from the water causes serious illness among the people who drink it. In such places the missing mineral matter must be added to the water or to the diet if health is to be preserved.



Good water and pure water are, therefore, not the same thing so far as drinking is concerned. We both like and need some of the impurities that water picks up in its wandering over the earth. Unfortunately not all the impurities that get into water are good for us. Keeping the good and getting rid of the bad impurities is one of the chief problems in providing the right kind of water.

Muddy Water. Much of the mineral matter in water consists of tiny but visible particles of soil. The particles in the water give it a "dirty" or "muddy" appearance. Nobody likes to drink muddy water. Fortunately mud can easily be taken out of water, as we can show by a simple experiment.

Exercise. How to remove mud from water: Place a teaspoonful of fine soil in a glassful of water. Cover the glass tightly and shake well. Place the glass of muddy water on a table and watch it for several minutes. Can you see the particles of soil? Are they rising or falling in the quiet water? Do some of them settle to the bottom? Do all of them settle to the bottom? Next fold a filter paper as shown above, and fit it into a funnel. Pour the muddy water slowly into the funnel and watch it seep through the paper. Catch some of the water in a clean glass. Does the filter paper remove any of the mud? Does it remove all the mud?

Many cities do in a large way what you have just done in a small way. They pump water into large *settling basins*, where some of the mud settles to the bottom. Then they put the water through *filtering plants*, where the rest of the mud is removed.

THE DISSOLVED IMPURITIES IN WATER

Solution. Water flowing over the ground picks up more than the tiny visible particles of mineral matter which make it muddy. It also picks up tinier *invisible particles* of mineral matter. These invisible particles do not ordinarily make the water cloudy or muddy. In some cases the water becomes colored, but in most cases it remains clear enough so that you can easily see right through it.

When water picks up mineral matter in the form of tiny invisible particles, we say that it *dissolves* the mineral matter. The process of dissolving is called *solution*. The resulting product is called *a* solution. Anything that will dissolve is said to be *soluble*.

Exercise. How to make solutions: Pour clean water into three clean glasses until each glass is about three-quarters full. Place a little sugar in the first glass, a little salt in the second glass, and a little copper sulfate (blue vitriol) in the third glass. Stir the water in each glass until the solid matter disappears. Can you see any particles of the solid matter in the water of any glass? If not, what has happened to it? Has the water in any glass changed color? If so, has it become cloudy or can you still easily see through it?

What you have done in the above experiment nature also does. Many different kinds of mineral matter are soluble. Small portions of even the hardest rocks, if soaked long enough, will dissolve in water.

These boys are examining part of the water system of a large city. This is a settling basin, where the water is allowed to lie quietly until the heavier muddy impurities settle to the bottom. Later the water will be passed through a filtering plant, which will remove the lighter particles of mud

Exercise. Name all the examples of solution that you have observed.

Getting Rid of Dissolved Impurities. Certain kinds of dissolved mineral matter make water smell and taste bad. Certain kinds are bad for our bodies. Certain kinds clog the machines in our factories and the pipes in our homes. How can we remove such mineral matter from water?

Exercise. Let the solution of copper sulfate which you have made in the last experiment stand for an hour or so. Does any of the mineral matter settle out? Filter the solution as you filtered the muddy water in an earlier experiment. Does any of the copper sulfate cling to the filter paper?

The above experiment will show you how *not* to get rid of mineral matter that is dissolved in water. Unlike the visible particles of mud, the invisible particles of copper sulfate are too light to settle and too small to be caught in a filter. There is a way of removing them, however, and an experiment will demonstrate it.

Exercise. How to remove dissolved mineral matter from water: Pour a little copper sulfate solution into a flat dish. Place the dish on a warm radiator and leave it there until all the water has evaporated. Does the copper sulfate evaporate with the water or does it remain in the dish?

Strictly speaking, this experiment does not demonstrate how to get rid of the dissolved impurities in water. It really demonstrates how to get rid of the water. To save the water we should have to boil the copper sulfate solution. Then we should have to catch the steam as it rises, and cool it until it turns back into the liquid form. In this way we could rid the water of its mineral impurities and still have the water.

Water that has been turned to steam and then turned back (condensed) into liquid water is said to be *distilled*. The process is called *distillation*. Distilled water is as pure as fresh rain water because distillation removes all impurities.

Exercise. Can you name any use or uses for distilled water?

Getting rid of dissolved impurities in water by distillation is a roundabout way of attacking the problem. There is a much easier way, as we shall see.

How to Deal with Hard Water. Water that contains a great deal of dissolved mineral matter is known as *hard water*. It is not harder than other water in the same sense

In the laundry hard water makes hard work

that a piece of rock is harder than a piece of dough. Hard water tends to chap and roughen the skin. It is hard in the sense that it is "hard on" the person who uses it. *Soft water*, on the other hand, contains little or no dissolved mineral matter and is "easy on" the skin.

Scientists have discovered a quick way of softening hard water. They have discovered that the old saying "Set a thief to catch a thief" will work in the mineral world. If a certain kind of mineral matter is added to water which is already "hard" with another kind of mineral matter, the two materials will combine and settle out of the water.

One of the disagreeable things about hard water is that it lathers soap very poorly. The laundryman merely adds washing soda to the water that comes out of the faucet. The washing soda combines with the mineral matter already in the water, and the two settle down to the bottom of the tub. The water is now soft; soap lathers quickly and abundantly.

Mineral Matter in Drinking Water. Perhaps you have not realized that every time you take a drink of water you swallow something besides water. A simple experiment and a simple observation will show you what this something is.

Exercises. How to find the mineral matter in drinking water: Place a drop of drinking water on a flat piece of clean glass, and put the glass where the water will evaporate. The mineral matter that was dissolved in the water will remain on the glass after the water has disappeared.

Go to the kitchen and study the inside of the teakettle. After removing the water do you see flakes or a crust of mineral matter on the inside of the kettle? Where did the mineral matter come from?

You should not be alarmed if you discover that the water you drink contains a considerable amount of mineral material. Unless too plentiful or of a harmful or disagreeable type, mineral matter gives drinking water a pleasant taste.

THE LIVING IMPURITIES IN WATER

Bacteria. Soil and dissolved mineral matter are not the only things that water is likely to pick up. You have already observed many kinds of living things in water, some of them invisible to the naked eye. Most of these creatures which only the microscope can bring to light are harmless. All of us "eat them alive" in great numbers every day and are none the worse for doing so.

Certain water plants that can be seen only under the microscope are exceptions to this general rule. They can do us great harm if we take them into our bodies. These one-celled plants are known as *bacteria* (singular, *bacterium*). Their name means "a stick" or "a rod." It was given to them because so many bacteria when seen through a microscope look like tiny sticks or rods.

Not nearly all the bacteria are harmful to us, but enough of them are harmful to give the whole group a bad name. Among the worst are the bacteria that cause typhoid fever. They get into water through sewage which contains waste from the bodies of people already suffering from this disease. Unless such waste has found its way into the water supply, harmful bacteria will not ordinarily be present.

Many bacteria look like tiny sticks

The Problem of Water Pollution. Water that contains harmful bacteria or other disease-producing crea-

THIS WATER IS UNSAFE FOR DRINKING

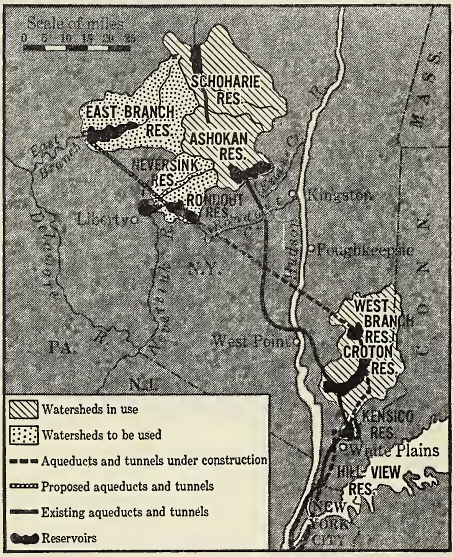
The boy with the cup is in very serious danger

tures is said to be *polluted.* Without careful laboratory tests it is impossible to know whether water is polluted. For this reason you should *never* drink the water in untested streams. Carry drinking water with you on your hikes and picnics. Health officials are always on the lookout for harmful bacteria in your local water supply. They kill the bacteria before the bacteria can kill you.

The boys in the picture above have come to a polluted stream in the course of a hike. If they are wise, they will not touch the water, however good and clear it seems to be. Unfortunately, not all polluted streams are posted with warning signs. To play safe it is better to assume that *all* unknown waters are polluted.

HOW CITIES GET ENOUGH GOOD WATER

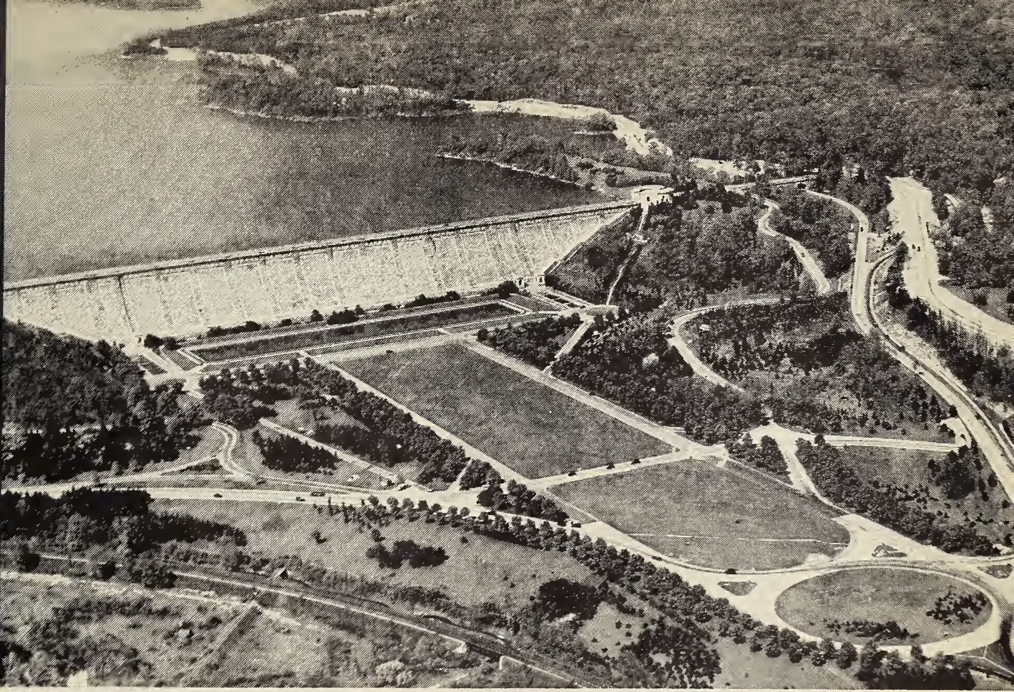
The Water Problem in Cities. An unbelievable amount of good water is needed for every city every day. Water for drinking is only a small part of the water that is needed. A much larger quantity is needed to keep the city and the citizens clean. In manufacturing cities still larger amounts are needed for factories and mills. The city of New York uses more than a billion gallons of water every day! If the water that flows through a million pipes in New York could be turned into a single stream, it would make a fair-sized river.



Where New York City gets its water

The Water Supply of New York City. We can best explain the water problem in cities by describing how one great city has solved it. Much of the water used in New York City comes from the Catskill Mountains, more than one hundred miles away. Study the map above and see the large area, or *watershed*, from which this water comes. Even this is not enough to supply the needs of the future. Arrangements are now being made for bringing great quantities of water to New York from a source that has never before been used.

At present, two large reservoirs store water which the streams bring down from the mountains. This water is



McLaughlin Air Service

reat cities need great reservoirs. This is a view of the Kensico Reservoir shown on the map on page 110

usually very clear, except after heavy rains. Although most of the mud that the rains bring in settles to the bottom of the reservoirs, special treatment is sometimes necessary to remove the mud that remains.

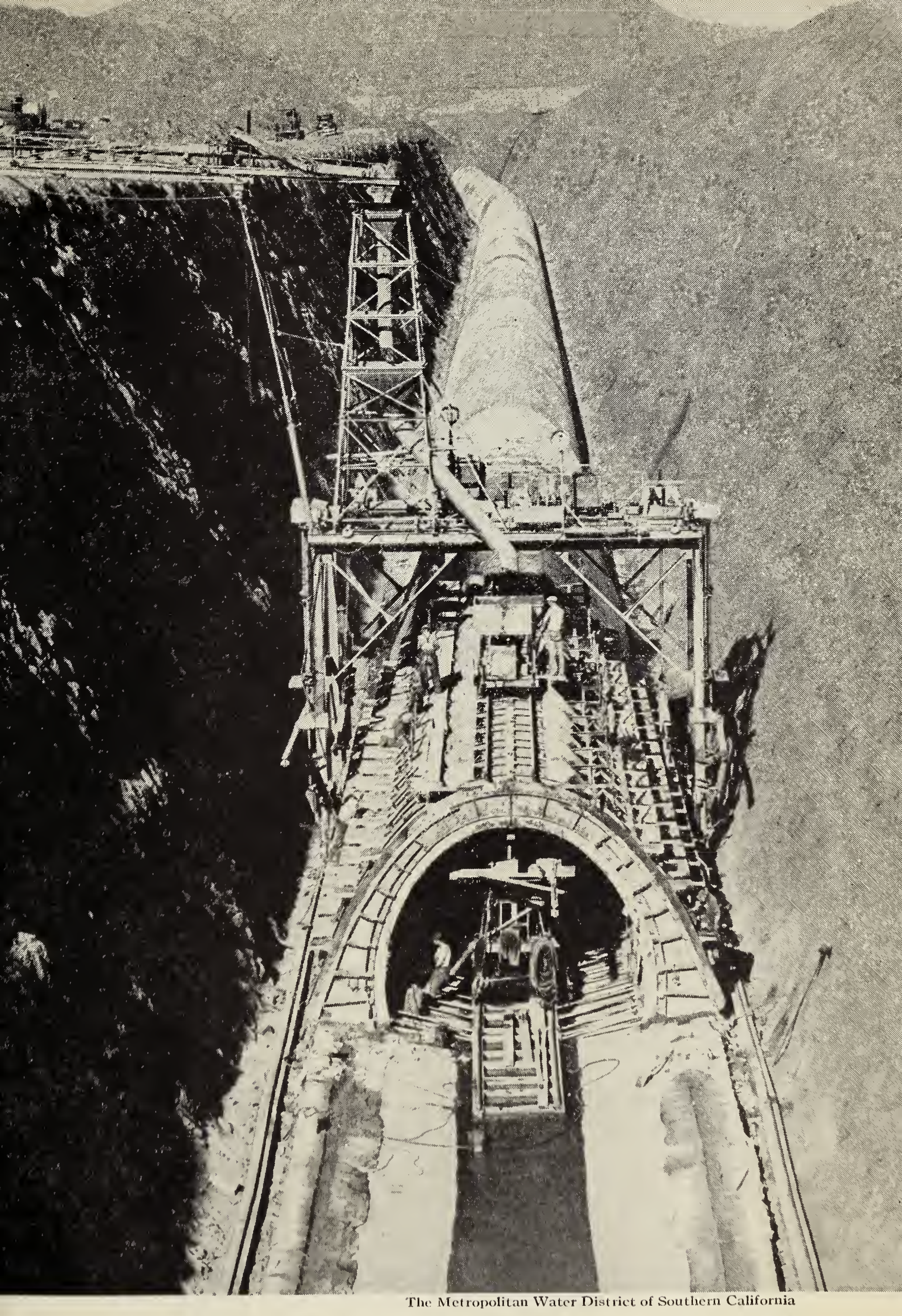
The next step in purifying the water is to kill any dangerous bacteria it may contain. For this purpose a small amount of the poison *chlorine* is used. So little chlorine is necessary for killing the bacteria that its presence in drinking water is entirely harmless to human beings. This step in purifying water is very carefully performed in the cities of the United States and Canada. You can assume that it is safe to drink the water you draw from any city faucet in these countries. If it is not safe, the health officials will see to it that the public knows.

A further step in purifying water is the removal of dissolved mineral matter. Such a "softening agent" as we described earlier in this chapter is sometimes added to city water. This combines with the dissolved mineral matter and causes it to settle out. Fortunately for New York, the water from the Catskill streams contains so little dissolved mineral matter that it is not necessary to remove it.

The final step in purifying water is the removal of bad odor and bad taste, which are caused by leaves and grass that have decayed in the water. Though harmless they are in some cases very unpleasant and must be removed. The water is therefore sprayed into the air in an *aeration plant.* In aeration (which means "mixing with air") oxygen from the air is dissolved in the water. At the same time the water is exposed to sunlight. Oxygen and sunlight destroy the unpleasant odor and taste.

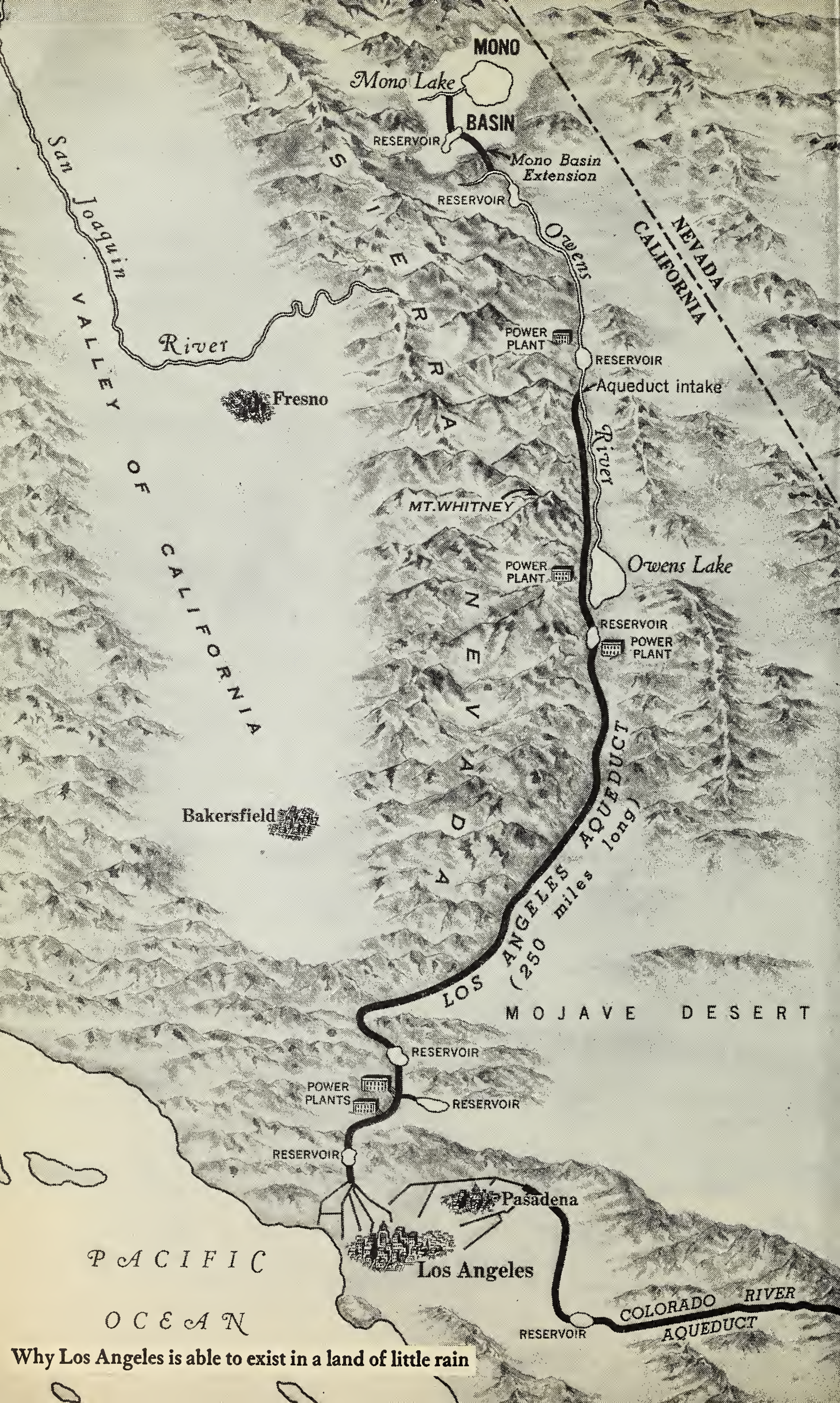
The work of building reservoirs such as the one shown on page 111; of building *aqueducts* (great pipes or open runways) to carry the water from the reservoirs to the city; and of laying pipes to distribute the water to the houses, office buildings, and factories of New York City is a gigantic task. It is a task that is never finished. New sources of water must continually be found, and new pipes must continually be laid to take care of the ever-increasing demand for water.

The main aqueduct from the Catskill Mountains to New York City is a tunnel large enough for a freight train to pass through. Starting in the mountains 1000 feet above the sea, it burrows through mountains and under rivers which lie across its path. About 50 miles above the city it dives beneath the Hudson River. Here the engineers had to blast through solid rock far beneath the bed of the river. At its greatest depth the aqueduct is more than 1500 feet below the level of the ground. It is one of the greatest engineering feats in the world.



The Metropolitan Water District of Southern California

apidly growing cities in dry regions are forever outgrowing their water supply. Here e men at work on a great modern aqueduct. Recently completed, it carries water many miles from the Colorado River to the city of Los Angeles



Why Los Angeles is able to exist in a land of little rain

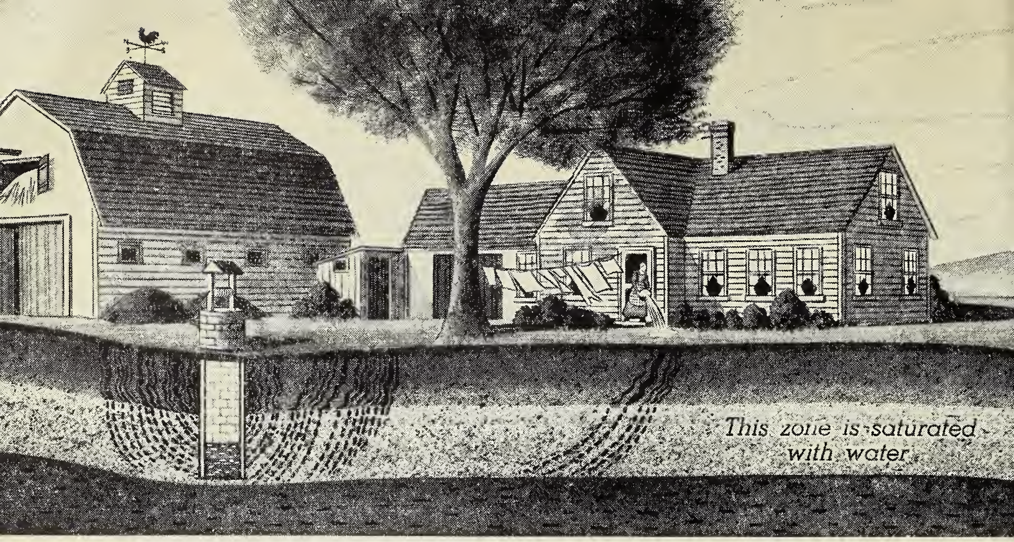
The Water Supply of Other Cities. Several cities take their water from a single river. Minneapolis is such a city. It is built on the banks of the Mississippi, and it gets its water from that river. The water is muddy and sometimes contains harmful bacteria. It is first pumped from the river into a reservoir, and there it is treated to remove some of the mud. Then it is pumped into another reservoir, where chlorine is added to kill the bacteria. After this it is safe and pleasant to drink.

Chicago takes its water from a point far out in Lake Michigan. Los Angeles is supplied from mountain lakes far away in the high Sierras and from the distant Colorado River. The map on the opposite page shows how Los Angeles gets its water. Modern engineering has thus made it possible for one of the largest cities in the United States to exist in a very dry land.

SAFE WATER IN THE COUNTRY

The Water Problem in the Country. In the city one can have excellent water at all times merely by turning a faucet. In the country the water problem is not so simple. Water in rural communities is usually taken from wells, sometimes from springs or cisterns. Occasionally it is piped from neighboring streams or ponds. This last source is always dangerous, because the possibility of pollution is great. Rubbish and other undesirable matter may be thrown into the streams or ponds. Rain water as it flows over the ground may carry unclean material into the water supply.

Protecting Wells and Springs. Whatever the source of supply, however, care must be taken to avoid pollution. One simple precaution is to make it impossible for running


This zone is saturated with water

How many sources of pollution does this picture show?

surface water to get into the well or spring. This may be done by building a tight, close-fitting cover for either of these sources of water supply. A ditch may be dug around the well to carry off such surface water as may flow toward it. The well or spring may be fenced in to keep out poultry, cattle, and other animals that might pollute the water. Above all, drainage from outdoor toilets or cesspools must be kept from reaching the water supply.

Exercise. Study the diagram above. What precautions have been taken to protect the water supply on this farm? What precautions might have been taken?

The water in a well or spring has seeped or flowed through the ground. If there are sources of pollution close by, such as a cesspool or a barnyard, it is quite possible for harmful bacteria to seep through the ground and into the water supply. For this reason the location of the country water supply must be carefully studied. *It is always wise to locate a well on the highest ground possible.* This in itself, however, is not sufficient protection, because the level of the water in the well may be below that of a neighboring cesspool or other source of pollution.

What to Do When in Doubt. In general, water from shallow wells should always be distrusted. One should always consider that water from a spring or stream is bad unless it has been tested and found good. *All water used for drinking should be tested regularly.*

This testing should be done in a scientific manner. We sometimes say that water which looks and smells clean *is* clean. But it *may not* be clean. Unless you are quite sure that water from a well or spring is safe to drink, boil it before you drink it. Boiling kills the bacteria. The water should be heated until large bubbles break at the surface. And finally, remember that it is much safer to boil doubtful water too long than not long enough.

Correct These Statements

The following statements are partly or wholly false Correct them and discuss your corrections.

1. Modern cities are never threatened with water famine as ancient cities frequently were.
2. Pure water and good water are the same thing.
3. Rain water is the best-tasting water in the world because it is the purest.
4. Mineral matter in water is always harmful.
5. If muddy water is allowed to stand long enough, all the mud will settle to the bottom.
6. Filtering is the best way of removing dissolved mineral matter from water.
7. The only way of softening hard water is to distill it.
8. The mineral matter in water makes soap lather quickly and abundantly.

9. All mineral matter has been removed from the water we take from the faucet.

10. All the bacteria that live in water are harmful to us.

11. In purifying the water supply, our large cities are not very up-to-date.

12. Safe water is more easily found in the country than in the city because there are fewer people in the country to pollute the water supply.

Questions for Discussion

1. Suppose you were given a liquid which you suspected contained a colorless substance, such as salt or sugar, dissolved in it. How could you tell without tasting it whether or not such a substance was dissolved in the water?

2. Do you think it is a good thing for a community to spend large sums of money for the purpose of securing a safe water supply? Is it fair to tax everyone to pay for such a water supply, regardless of private opinions in the matter? Give reasons to support your answer.

3. Why is sewage disposal important in connection with a safe water supply? How far should a community go in controlling the amount of industrial wastes and sewage dumped into near-by waters?

4. Water obtained from deep wells is usually free from bacteria. Why?

Things to Do

1. Take a dish of salt water and a dish of rain water. Test them with soap to see which is hard and which is soft.

2. Find out about the source of the water you drink. Make a diagram or map showing how it comes to you. If

you live in the country, find out how deep your well is. Are all the wells in your community about the same depth? Why?

3. Look up references on water supply and see how many different ways you can find in which communities get their water. You might write to the water departments of a number of cities and ask them to send you any information they may have concerning their water supply.

4. Alum is used to take dirt out of the water in swimming pools. You might like to see how well the alum works. Mix a little black mud with water in a test tube and add to it a few drops of ammonia or limewater. Shake the mixture thoroughly. Now add a small bit of alum and shake it again. You will be surprised to see how quickly the mud settles out after you stop shaking it.

5. Prepare for your class a booklet on your community water supply. Obtain accurate historical and up-to-date information, and illustrate with photographs, diagrams, or sketches. If possible, take your own photographs.

6. Obtain accurate figures concerning the death rate due to typhoid fever in your community before and after the community water supply was supervised by public authorities. Your local health officer can probably furnish the needed information. What conclusions do you draw?

7. You may like to read the chapter in De Kruif's *Microbe Hunters* which tells of the search for the typhoid-fever bacterium. This is an excellent description of the work of the scientists who have helped us to live healthier lives.

8. Plan and set up a model water-supply system such as the one you have in your community.

9. Write a list of "Dont's" which you think might be used in connection with the selection of a good water supply.

CHAPTER SIX

How We Use Water in Our Work

WATER FOR POWER

Water is a Willing Servant. Much the greatest service of water to man is in quenching his thirst. Without water to drink a man could not live a week. Water, however, is far more than a drink. It is a servant that helps us in a thousand ways. We have had glimpses of some of the ways in the earlier chapters of this unit. In this final chapter of the unit let us take a closer look.

Work and Power. When you tug at a piano that will not budge, you think of yourself as working very hard. In the scientific sense of the word "work," however, you are not working at all. You do no work until the piano begins to move. *Work, in other words, is the movement of an object by some force.*

Let us say that it takes you five minutes, but your father only one minute, to move the piano from one place to another in the room. Both you and your father do exactly the same amount of work, but your father does it five times as fast as you do it. He is, therefore, five times as "powerful" as you are. *Power, in other words, is the rate of doing work.*

All creatures must work or die. They must forever *move* themselves and other objects in order to gain the things which make life possible. Much of the history of man deals with his attempt to get more work done more *quickly*, that is, to increase his power. Very early in human history men discovered tremendous power in running water. By developing this power through the ages, they have been able to get water to work for them on a truly gigantic scale.

The Weaknesses of Muscle. A large part of the history of the early white settlers of New England, for example, is the story of how they got water to work for them. In the beginning they used their own muscles and a few crude tools to saw logs for their cabins, to grind meal for their bread, and to spin yarn for their clothes. The picture below shows two common forms of muscle work. Few people regularly do this sort of work today. In the days of our ancestors everybody did it.

You will notice that the woman is pumping the spinning wheel as you would pump a bicycle. A belt connects the

he early days much work was done with muscle and a few simple tools and machines

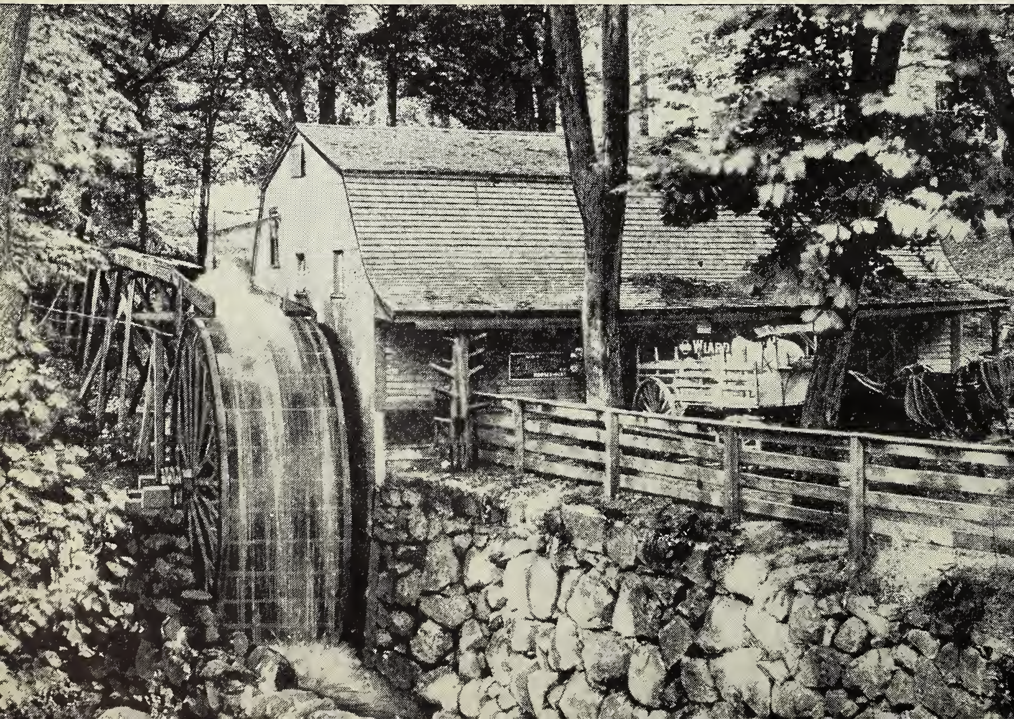
large wheel with a small wheel, which turns the spindle that spins the yarn. When the woman stops pumping, the spindle stops turning.

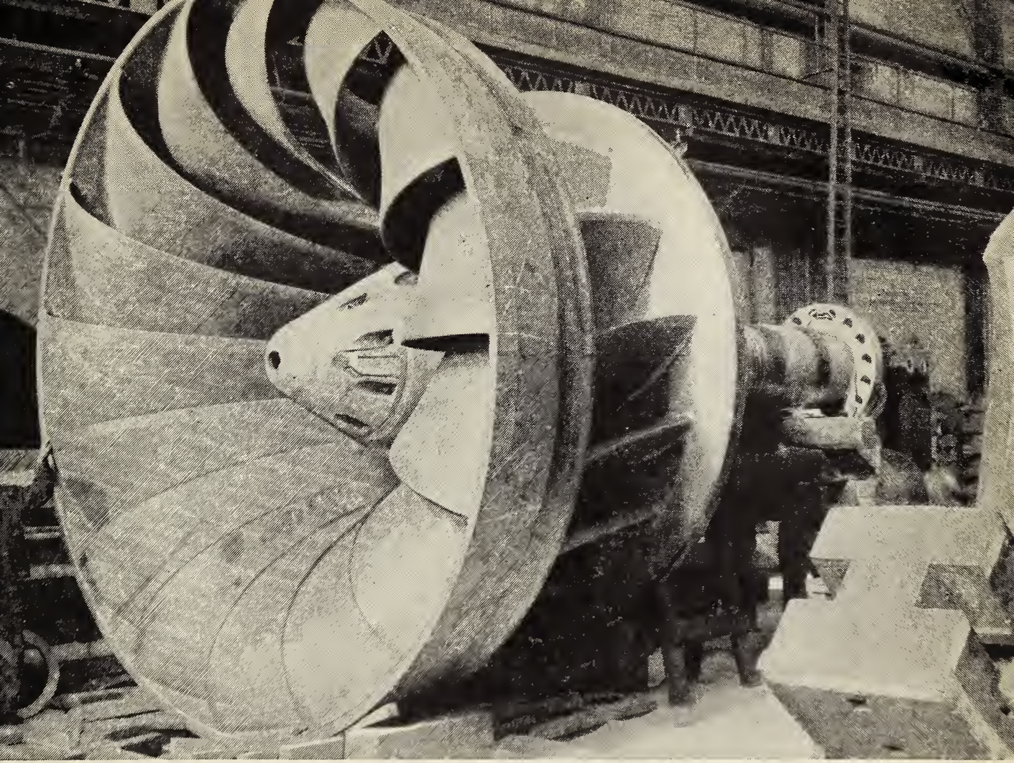
Muscle Has Two Great Weaknesses as a Worker. It can do only relatively easy work, and it can work only relatively short periods without rest. The woman must often stop pumping the spinning wheel to rest. Each stop slows down the production of yarn. If only there were some easier way of turning the wheel, more yarn could be produced in less time.

From Spinning Wheel to Turbine. We all know that there is an easier way. In fact, there are several easier ways. One of these ways lay right in the early New England settlers' own back yard. New England is full of short but swiftly flowing rivers. Why not let the rivers turn the spinning

Here is the simplest way of making water work

Galloway





Allis-Chalmers Manufacturing Co.

The modern water turbine is merely the old-fashioned water wheel grown up

wheels with the power that they waste each day against the rocks? Men in other lands had learned how to make water turn wheels which would not have to stop while weary muscles rested. The muscles of running water need no rest!

New Englanders were not slow to recognize the value of their rivers. They learned how to make them turn wheels, and they learned how to make the wheels do many kinds of work. Chiefly they made them saw wood, grind flour and feed, spin yarn and cloth.

Exercise. The photograph on the opposite page shows a simple water wheel in operation. Explain how the wheel catches the water and how the water turns the wheel.

Many New England people went with the water wheels to the rivers. Industries moved from scattered homes in the hills to fast-growing towns and cities along the streams. "Mill towns," where water took the place of muscle, became the chief centers of population.

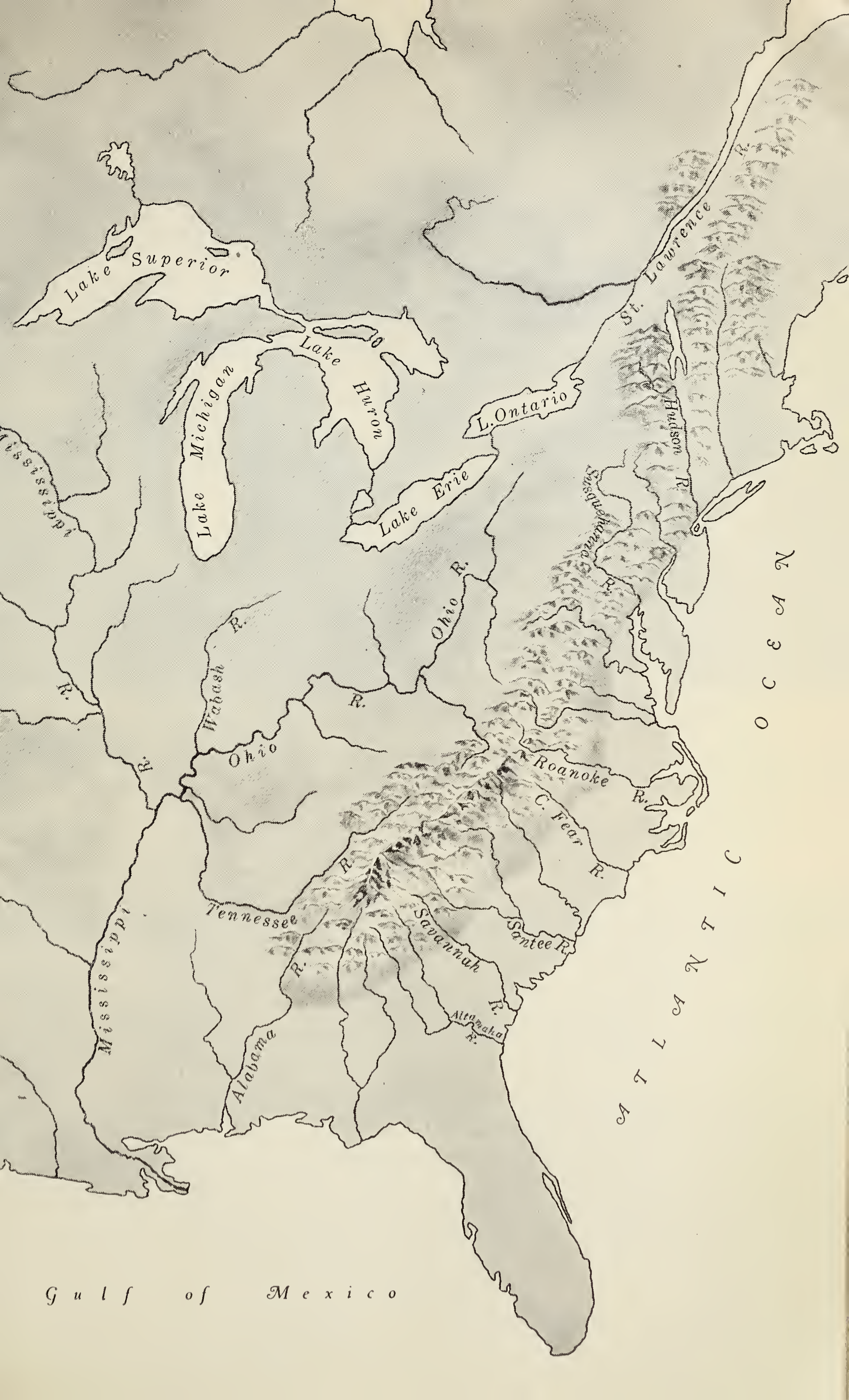
What happened in New England happened later elsewhere. Colonists moving to the south and west made the rivers work for them wherever this was possible. Gradually the old-fashioned water wheel was replaced by the modern *water turbine* (see page 123), which is merely the water wheel improved and brought up to date.

Not All Water Will Work. Water is the cheapest and easiest source of power in the world—when it *is* a source of power. Like human beings, some kinds of water are better workers than other kinds. Some kinds will not work at all. What is it that makes some waters good sources of power and others poor?

Running Water and Work. Water which is not moving can no more turn a wheel than a bicyclist whose legs are not moving. Only such waters as move fairly rapidly, or can be made to do so, will work. Accordingly, water that flows over a steep slope is a better worker than water that flows over a plain. The upper Mississippi River, for example, where the land is steep, develops forty-three times as much power as the lower Mississippi, where the land is almost flat.

Exercise. Study the relief map of the eastern United States shown on the opposite page. What rivers or parts of rivers appear to be good sources of power? What rivers or parts of rivers appear to be poor sources of power?

Waterfalls, Rapids, and Work. Have you ever noticed that the names of many cities where water power is developed


Lake Superior
Lake Michigan
Lake Huron
L. Ontario
Lake Erie
St. Lawrence R.
Hudson R.
Susquehanna R.
Mississippi
R.
Ohio R.
Wabash R.
Ohio R.
Mississippi R.
Roanoke R.
C. Fear R.
Tennessee R.
Savannah R.
Santee R.
Altamaha R.
Alabama R.
ATLANTIC OCEAN
Gulf of Mexico

Galloway

The waterfall determined the location of this power plant on the Spokane River, Washingto

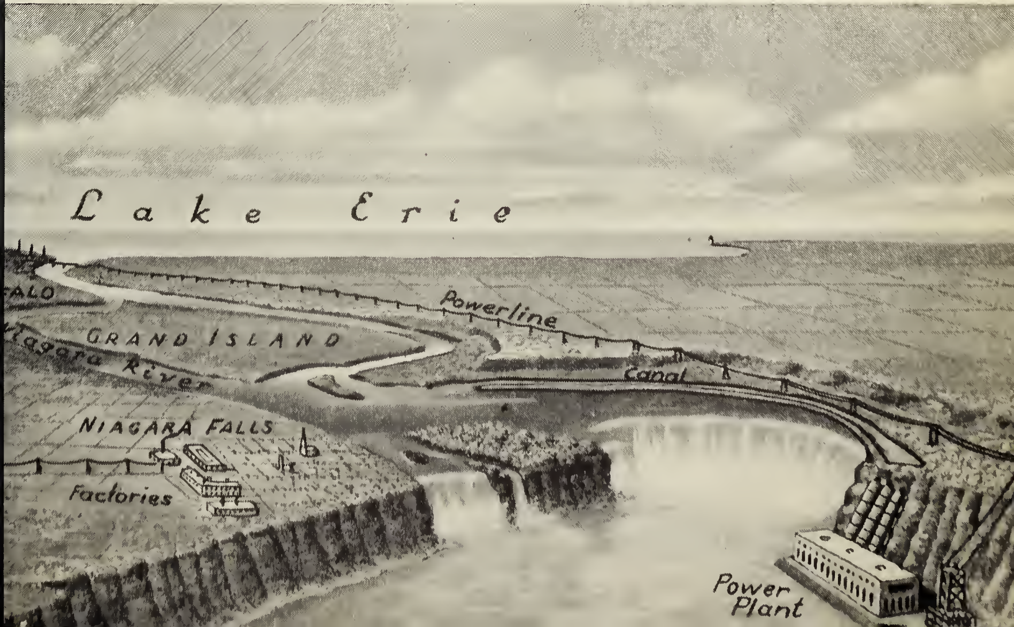
contain the words "falls" or "rapids"? There are, to mention only a few, Niagara *Falls*, New York; Great *Falls*, Montana; Iroquois *Falls*, Ontario; *Fall* River, Massachusetts; Grand *Rapids*, Michigan. These cities are located on rivers at points where the water drops over a ledge of rock (waterfall) or where it moves over an uneven stretch of land that churns and roughens it as it flows (rapids). At such places rivers move fastest and develop the most power. Such places are also convenient for building dams to harness and control the power. The photograph above shows a water-power plant built at a waterfall in a river.

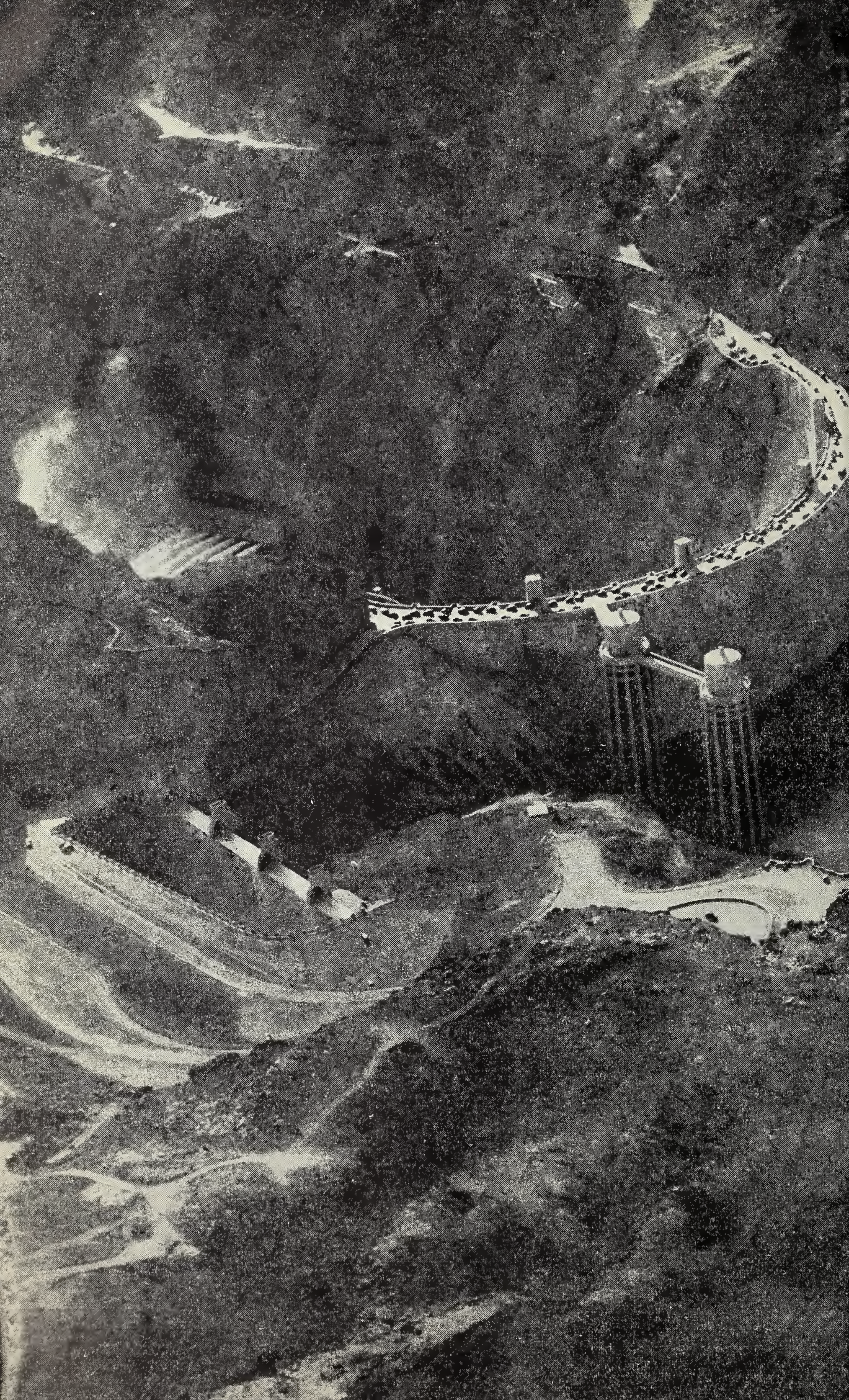
Exercise. Make a list of as many cities as you can find that are located near waterfalls or rapids in rivers. Do these cities develop their water power?

The Importance of Steady Flow. Rivers that do not vary much in speed from season to season are the most reliable sources of power. Many streams in the rugged mountains of California flow too irregularly to be dependable workers. During the winter rains they are powerful giants, but during the dry summers they are weaklings. Some of them dry up completely in summer. It would not pay to build power plants on such rivers. The plants would be idle every summer—even if they were not destroyed in winter by the floods.

The Importance of Lakes and Reservoirs. Lakes help to control the speed of many rivers. *A lake at the head of a stream tends to store up the rain that falls on the watershed and to feed it slowly and regularly to the stream.* Lake Erie, for example, regulates the Niagara River, which flows out of it, so that the river varies little in speed or size from

How Lake Erie regulates the power of Niagara Falls





season to season. This is one reason why Niagara Falls is one of the finest water-power sites in the world. On page 127 is a diagram that will show you the relationship between the lake, the river, and the falls.

Men, learning a lesson from nature, have been able to regulate the flow of many rivers. By building dams across them they have caused the water to spread out in artificial lakes where no natural lakes existed. The photograph on the left shows Boulder Dam and part of Lake Mead, which has formed behind it. By means of this great dam the wild Colorado River is being tamed. It is being made to work steadily and with complete obedience to the will of man. Boulder Dam is one of our greatest triumphs over the world of water.

The Importance of Abundant Rainfall. Rainfall is the source of all water power. Only where rain is regular and abundant can water power be developed. That is one reason why the states of Washington and Oregon alone furnish more than a quarter of all the water power in the United States. That is why desert Nevada, though rugged, furnishes practically none.

The Future of Water Power. It is estimated that the United States uses only about one sixth of its water power. The remaining five sixths represent perhaps its greatest unused wealth. Though Canada's chief industry, the manufacture of paper from wood pulp, has led to the harnessing of many streams, much of the country's vast wealth of water power is also as yet undeveloped. It is certain, however, that much of this idle wealth will not remain idle much longer.

In the early days of water-power development men had to use the power where it was taken from the water. They knew no way of carrying it far from the banks of the rivers. Many good places for the development of water power were too rugged or too far from the centers of civilization to make it possible to build large mills and factories. Much of the country's water power had to be wasted.

Things are different now. We have learned to change the power of water into electricity, and to carry it through wires for hundreds of miles. We shall learn later more about how this is done. It is enough to know now that electricity can bring the power of the most distant mountain stream into our factories and homes.

It is reasonable to assume that very soon only those streams will be free which we have fought to keep free for their beauty. Not so long ago the conquest of nature by industry was a pressing problem. Today the rescue of nature from industry is a pressing problem. We should not allow industry to destroy the wild beauty of all our streams. There is room for both beauty and industry in our broad rich land.

Exercise. Make a list of all the ways you can discover by which the people of the United States are fighting to save the natural beauty of their rivers.

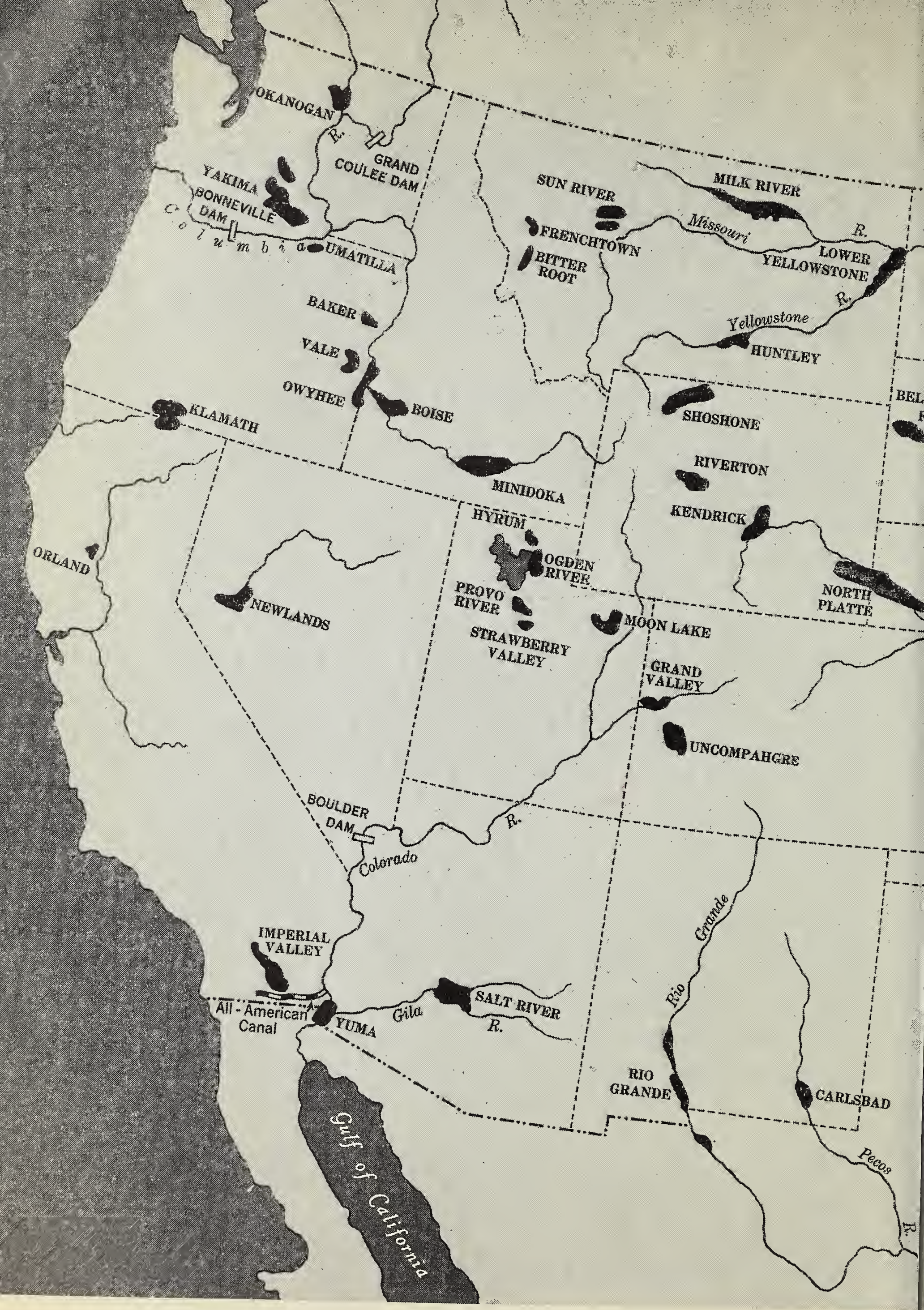
WATER FOR IRRIGATION

What Irrigation Is. Have you ever watered the lawn on a dry summer day? If so, you have practiced irrigation. "To irrigate" means merely "to water." Irrigation may be a simple process, such as watering the lawn, or a complex process that includes dams, reservoirs, thousands of miles of ditches, and thousands of square miles of farm land.

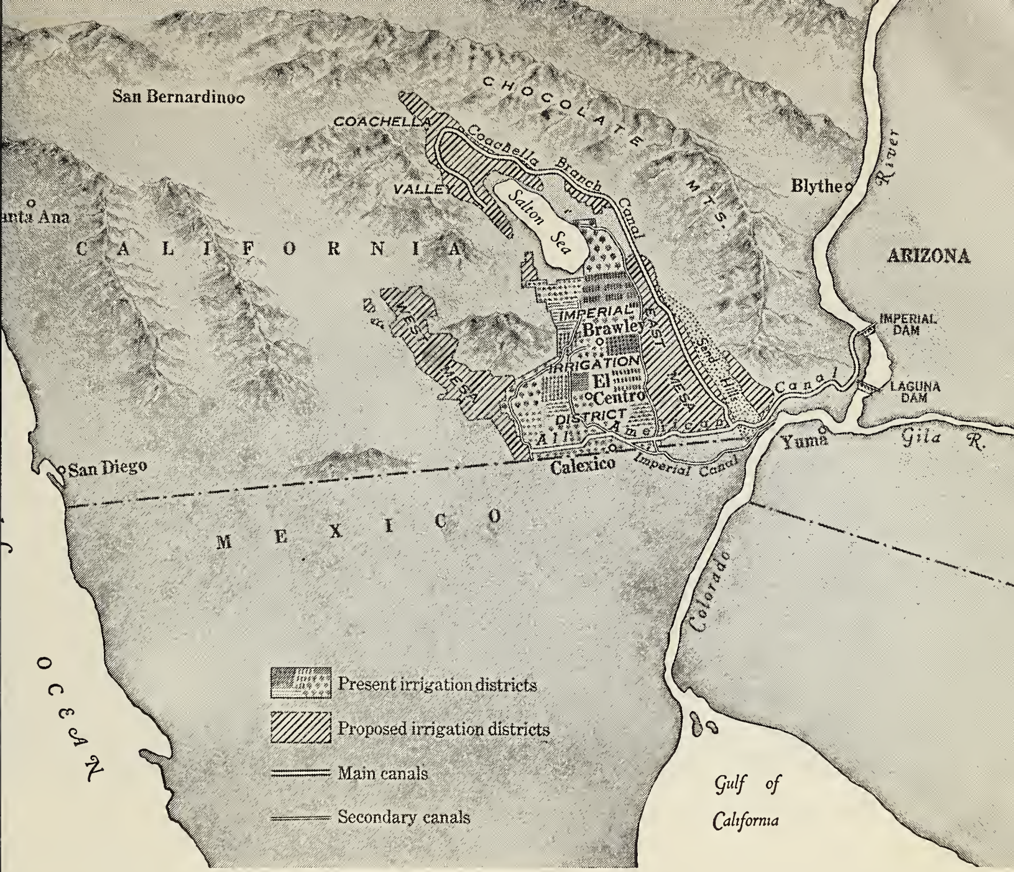
If you live east of the Mississippi River, where rain is plentiful and usually well distributed through the summer months, you probably have no idea of the importance of irrigation. Farther west the sky is less dependable. Rain is less plentiful and less evenly distributed through the summer months. In much of the far-western part of the United States rain alone would not produce the food which the inhabitants need. The very lives of more than a million people in the Far West depend on irrigation.

Exercise. Study the map on page 132. The black areas on the map show the chief irrigation developments of the western United States. How many states have found it necessary to develop irrigation on a large scale?

Imperial Valley. Let us look more closely at one of these irrigation developments. On page 133 is a map of the great Imperial Valley region in southernmost California. Until 1900 Imperial Valley was one of the hottest and driest deserts in the world. It was good for nothing.



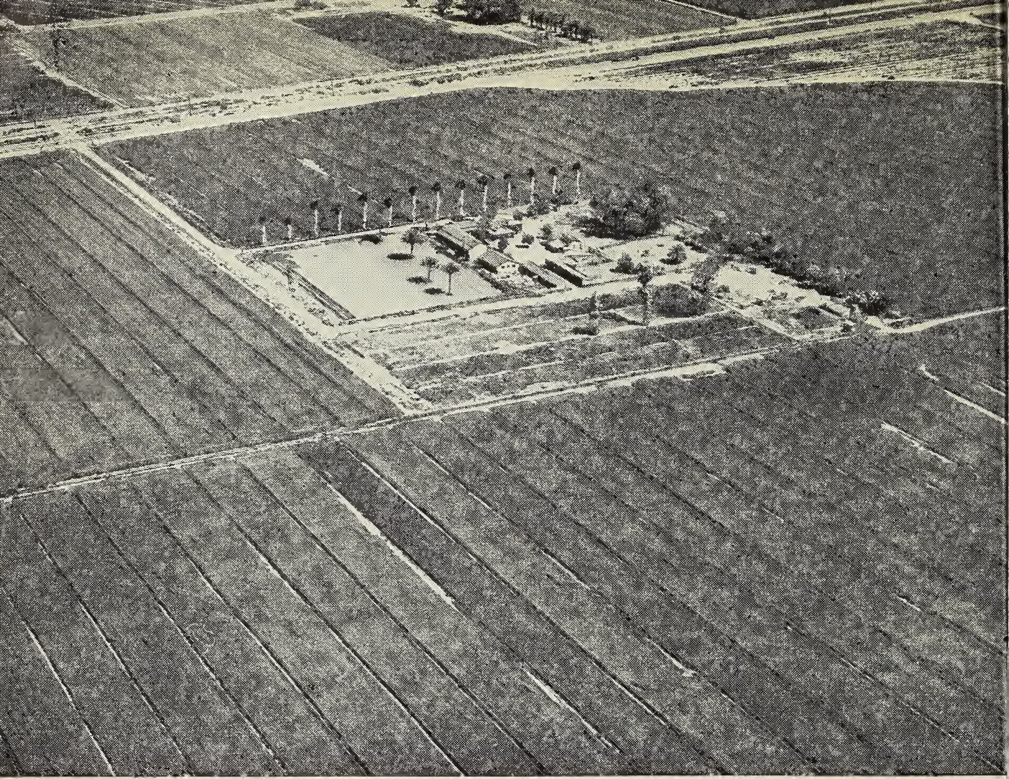
The black spots on this map represent important irrigation projects



is map shows how Californians use water from the Colorado River to irrigate the Imperial Valley

Californians, however, had observed that this valley lay many feet below the level of the sea. Though open to the Gulf of California at its lower end, it had not been filled with sea water because the Colorado River had built a great dam of sand and gravel at that point. Californians had also observed that the river as it neared its mouth flowed at an elevation of hundreds of feet higher than the floor of the near-by valley.

Why, they asked themselves, could not some of the river water be turned downhill toward the valley, and by a system of dams and ditches be made to water the waterless land? It could, and in time it was.



Spence Air Photo

This Imperial Valley farm is a miracle of water. Notice the ditches that have helped to turn a desert into fertile fields

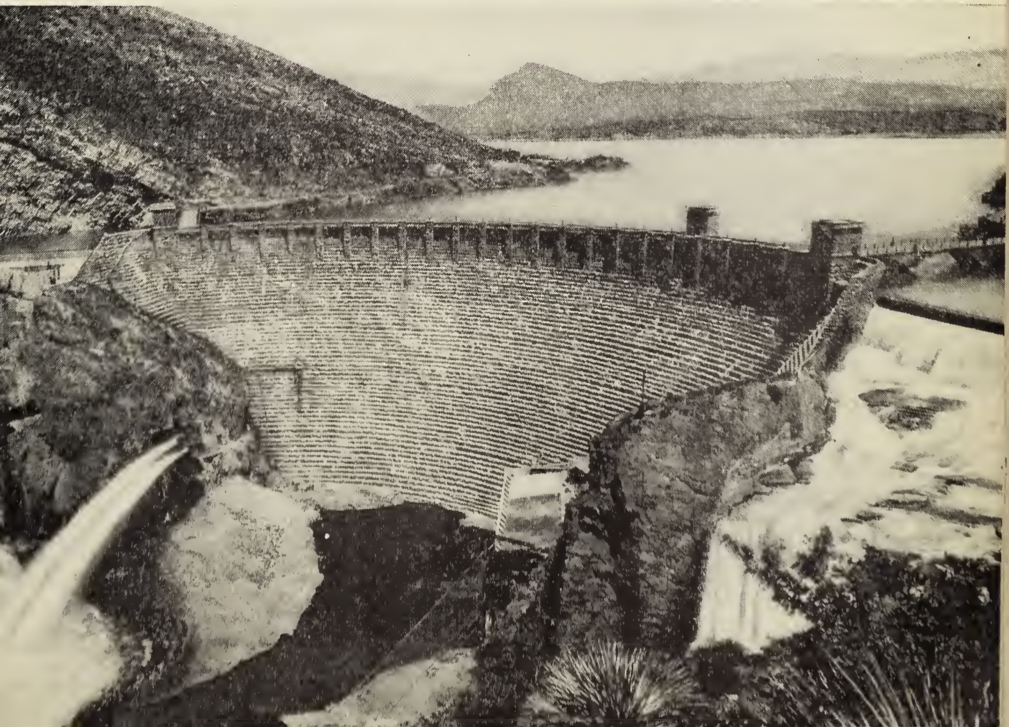
The Magic of Irrigation. The parched body of the Imperial Valley desert came to life with the magic touch of water. Almost a rainless land, it was unusually rich in minerals that nourish plants and which rain tends to wash away. A hot sunny land without frost, it was a natural nursery for delicate food plants, once water began to seep through its soil.

As though a fairy had waved her wand over its brown earth, the Imperial Valley suddenly turned green. Some of the richest farms in the world sprang into existence almost overnight. Cotton, dates, melons, and a host of other things began to be grown in great abundance. Irrigation had turned a worthless desert waste into one of the richest treasure houses on earth.

Mountains and Irrigation. Imperial Valley illustrates only one method of irrigating dry lands. There are many other methods. *Most methods of irrigation depend on the presence of mountains near the lands that are in need of water.* Throughout the dry regions of the globe the mountainous areas are better watered than the flat areas at their feet. The mountains not only catch the rain but they act as natural reservoirs to store it.

Some of the rain seeps into the rocks high up on the mountain slopes and later seeps out lower down in springs. Some mountains are high enough to have snow fields that do not entirely melt away until summer. These snow fields give out their water slowly and at the time when it is most needed by the farm lands below. Finally, mountain canyons are easily dammed. Reservoirs can be built there for storing rain, and the water can be allowed to flow down to the farms as it is needed.

The Roosevelt Dam is the guardian of many Arizona farms



The picture on page 135 shows the great Roosevelt Dam and Reservoir in Arizona. By means of this development, water that falls on a desert mountain range during the rainy season is preserved for irrigating the flat lands around the mountains during the dry season. Over half the farms in Arizona are supported by this single irrigation development.

The Value of Irrigation. Irrigation not only makes food plants grow where they could not otherwise grow, but it protects them from many of the natural risks of weather. If there is sufficient water in the reservoir, an irrigated farm never suffers from too much or too little water—so long as the farmer pays his water bill.

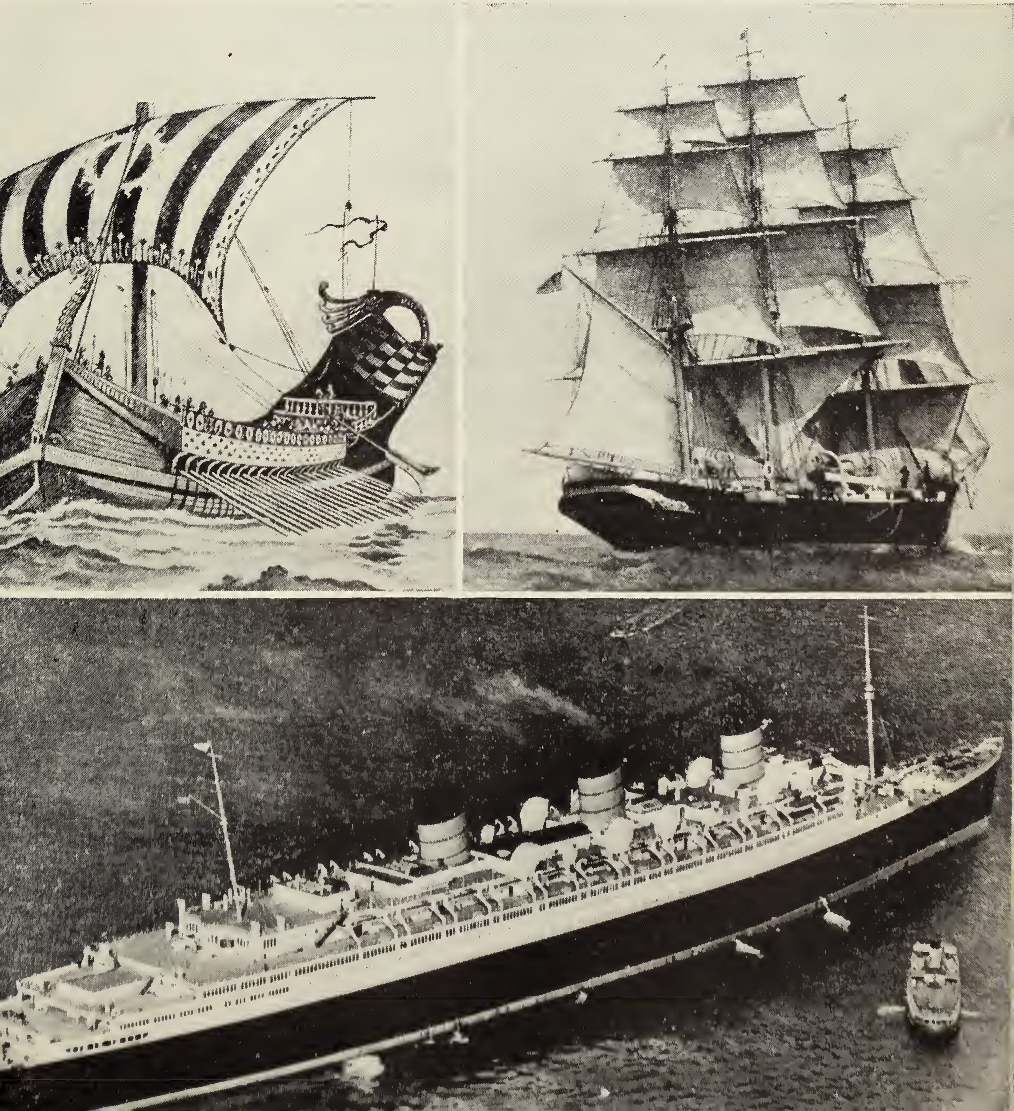
Because most irrigated lands are in warm sunny regions and rich in the mineral foods that plants must have, the crop is almost certain to be good. Indeed, the crop from an acre of irrigated land in the United States is from a quarter to three-quarters *more* valuable than the crop from an acre of unirrigated land.

Irrigation and Civilization. When we count the victories that men have won over nature, we must place irrigation high in the list. Egypt, for example, was one of the earliest centers of civilization. We still profit by the arts and sciences that were developed there centuries ago. Egyptian civilization would not have been possible without irrigation, because Egypt is naturally a desert.

Not only in Egypt but in China, India, and elsewhere, irrigation has promoted progress. Even long centuries ago the people in irrigated regions did not wander around and live the lives of hunting savages. They lived in one place, and they learned to take pride in their homes. They lived in communities of homes, and they learned to govern them for the general welfare. They developed wealth, and they learned how to make it produce good things for both body and mind. In short, they became civilized.

WATER FOR NAVIGATION

The Oceans as Workers. So far we have considered only the work done by lakes and streams. How about the mighty



First muscle, then wind, then steam was used to drive ships across the sea

T. F. Hartley and Ewing Galloway

oceans? Do these greatest of waters just idly lie in their beds or do they work for us too?

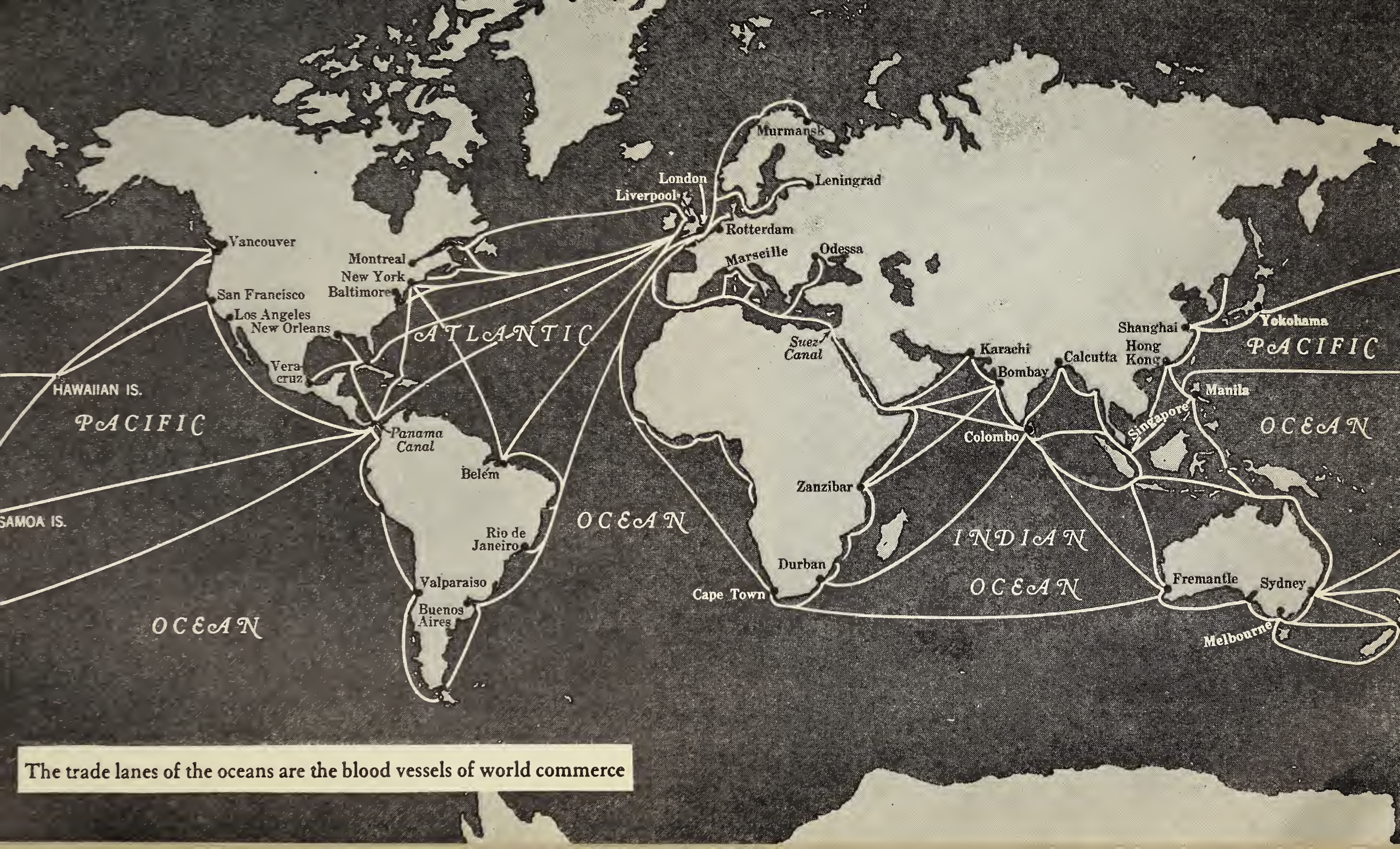
At first sight it might seem that the oceans do very little work. It might seem that they are not worth the space they occupy on the surface of the earth. Their waters are too salty to drink. They turn no wheels and they irrigate no fields. What good do they do us, then?

The Oceans Float Our Ships. Among other things, the oceans float our ships. They provide free, broad, and relatively flat highways for all who can invent ways of traveling them. From the beginning of civilization men have used these highways. Indeed, navigation (which means "the act of driving ships") and civilization grew up together. On page 137 are pictures of some of the stages of growth in the art of navigation.

What Ocean Navigation Does for Us. Navigation has changed the oceans from great barriers that separated the peoples of the world into great carriers of trade that unite them. Every day we use articles that were brought to us in ships from other lands. Every day the people in other lands use articles that were brought to them in ships from us. Navigation has made partners of all the civilized nations of the world.

Exercise. Make a list of things which you know came wholly or partly from other lands in ships.

On the opposite page is a map of the world with the main lanes of ocean trade and travel stamped upon it. These lanes are in a sense like the blood vessels in our bodies. They carry the blood of trade, which nourishes the commerce of the world.



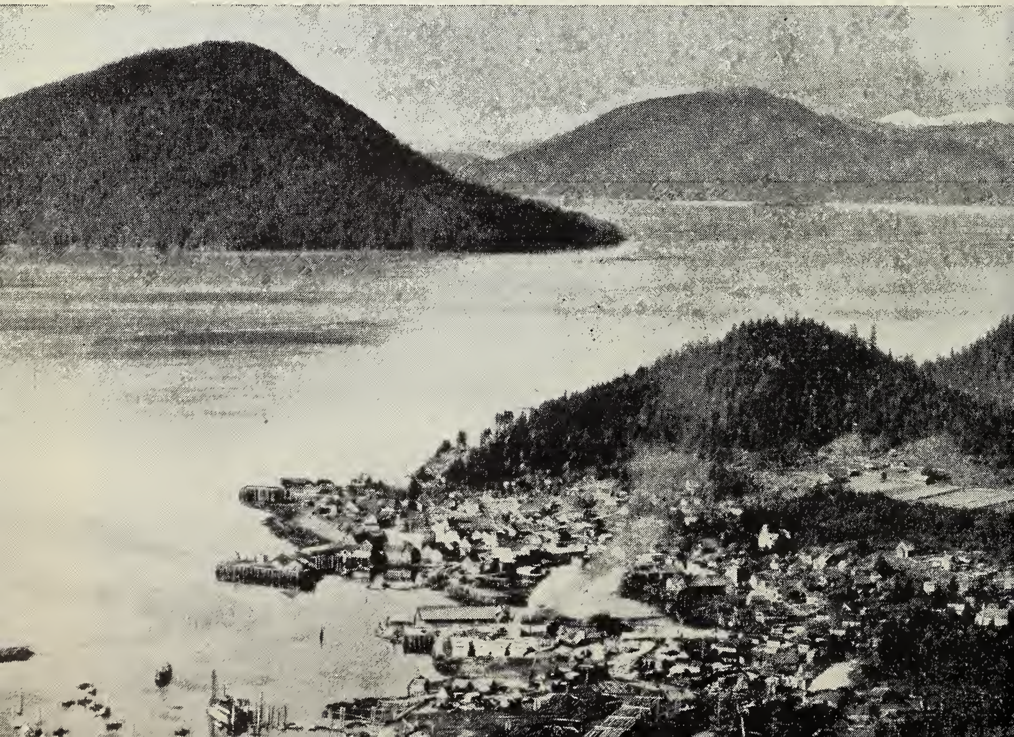
The trade lanes of the oceans are the blood vessels of world commerce

James Sawders

The harbor of Rio de Janeiro is large and deep and highly developed

The harbor of Wrangell is large and deep but only partly developed

Canadian National Railways



How Seaports Are Made. You will notice that many of the ocean trade lanes have great cities (seaports) at their ends. What is it that determines the position of trade lanes and seaport cities?

Before there can be either a trade lane or a seaport there must be harbors for ships. A good harbor provides not only protection against wind and wave for several ships but enough deep water near shore so that several large ships can unload their cargoes at once. The photograph at the top of the opposite page shows the harbor of Rio de Janeiro, one of the finest in the world.

A good harbor *alone* will not bring either ocean highway or seaport into existence. The photograph at the bottom of the opposite page shows Wrangell, Alaska, which is built on a fine deep harbor. It is only partly developed. Many other large harbors in Alaska are not used at all—excepting by fish. Why?

The answer to this question, as far as most harbors are concerned, can be put into a single sentence. *Harbors do not grow into seaports unless they are near some great source of wealth*, such as oil, lumber, wool, food, or an abundance of manufactured products. People near the harbors must produce more things than they need. They must also need some things that they cannot produce. Then, and then only, can they develop trade with other lands. Then sea lanes and seaport cities can come into existence.

We need only name the great cities of the world to see how important commerce by ocean has become. Two thirds of the world's largest cities are either on the sea or may be reached by seagoing ships.

Exercise. Can you name a seaport which is not on the sea?

Fresh-water Navigation. Though not as good highways as the oceans, lakes and rivers have played an important part in the development of many lands. Rivers are the easiest means of exploring an unknown country. They are the easiest means of moving about in an undeveloped country. In pioneer days lakes and rivers were the chief highways of travel and trade. The location of some of our most important cities was determined by these inland waterways.

Exercise. Can you name some large cities which are built on lakes or rivers? Can you reason out why they were built there?

Rivers are still the chief highways in large parts of Canada, Alaska, China, and South America. They are still important carriers of commerce in Germany and Holland. Generally, however, when a nation has built good roads and railroads, traffic on inland waters tends to disappear. Though cheap, fresh-water travel and trade are too slow and uncertain for modern needs.

Exercise. What are some of the things that make the navigation of rivers slow and uncertain?

THE WATER HARVEST

Food. We have seen how water may be used to irrigate fields so that food may grow where it did not grow before. We can also see that *water is itself a field for the production of food.* Creatures in great abundance live in the world of water. Many of these are easily harvested for the needs of men.

Along thousands of miles of seacoast, men add to the food they raise on land the food which they catch in the sea. Of all the food which the sea produces, the fishes are much the most valuable to human beings. In mountainous countries, where farming is difficult, such as Japan and Norway, fish is one of the chief foods of the country. In our own country fish is often found on the table, especially in homes along the coasts. Other water-dwelling creatures, such as lobsters, oysters, and clams, are frequently found there too.

Exercise. Look up the chief fishing ports of North America. Are most of them on northern or southern waters? Why do you suppose they are located where they are?

Fur. Water gives us fur as well as food. The Pribilof Islands off the coast of Alaska are the home of the largest herd of fur seals in the world. Every year the seals return to the same islands to breed. Their skins make a valuable harvest, as anyone can discover by pricing a sealskin coat. Otters, mink, and many other fur-bearing animals each year add value to the fur harvest.

These men are harvesting the sea's most valuable crop

U. S. Bureau of Fisheries

Galloway

Summertime is "watertime"

Exercise. Can you think of any other valuable things, such as food and fur, that we harvest from the world of water?

Fun. In listing the "crops" that water yields, we must not leave out fun. For many a boy and girl, and grown-up too, summertime is "watertime." It is the time for play at the old swimming hole or on a modern beach. It is the time for rowing, canoeing, sailing, and fishing. On countless lakes, rivers, and seashores countless people turn in summer to water for fun.

Health. Not least among the gifts of water to man is health. The oceans moisten the breezes, and this reduces the dryness of the air, which, when extreme, is harmful to health. They dilute and purify the sewage that hundreds of cities dump into them. Above all, they help to keep the temperature of the lands even, so that we do not fry in summer and freeze in winter.

Water has the property of heating up and cooling off less readily than land. As a result, the oceans are cooler than the lands in summer and warmer than the lands in winter. The winds that blow over the oceans are, accordingly, cooled in summer and warmed in winter. When they reach the lands, they tend to reduce the extremes of temperature, which are bad for health.

Exercise. Look up the average January and July temperatures of Portland, Oregon, and Bismarck, North Dakota. Which city has greater extremes of temperature? Why?

If it were not for the regulating effects of the oceans on temperature, all the people of all the continents would suffer terribly from both heat and cold.

THE CONSERVATION OF WATER

The Problem of Conservation. In Chapter V of this unit we learned what a serious matter it is when the water supply of a town or city is threatened with failure. We learned what great care must be taken to provide not only enough water for human needs but water which is free from pollution. Earlier in this chapter we learned that the development of water power is seriously threatening to destroy the wild beauty of all our streams. These problems, which have to do with the proper use and preservation of our American waters, are part of the great national problem of conservation.

The word "conservation" comes from a Latin word which means "to keep." *By conservation we mean the act of keeping, or protecting, our natural wealth from injury*

Milwaukee Public Museum

The snake dance of the Hopi Indians is not a show for tourists but a prayer for r

or loss. Nature has been generous in giving us the things we need for a rich and happy life, but we have recklessly spent our riches. We have recklessly spent not only beauty but also such practical things as forests, grasslands, and mineral deposits. We have destroyed, or nearly destroyed, such creatures as the passenger pigeons, which once darkened the sun with their wings, and the bison, which once moved in thundering herds across the Western Plains.

Many *natural resources*, as these gifts of nature are called, can be replaced, after having been wasted, only with the greatest difficulty. Many cannot be replaced at all. Once they are wholly gone they leave us forever poorer. We have learned through sad experience that we must use our wealth without wasting it. As we go on with our study of science we shall hear much about conservation. It is one of the mightiest problems in the world and one which science can do much to help solve.

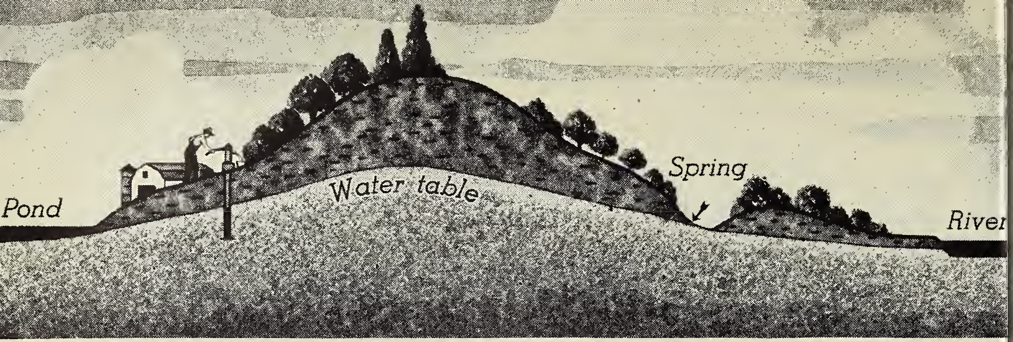
The Problem of Securing Enough Water. Remembering the story of the water cycle in Chapter IV, you might come to the conclusion that since no water ever escapes from the earth there is no special need for conserving it. Though water is forever traveling from place to place in rivers, oceans, and clouds, there is always the same amount on the earth as a whole. Since about three fourths of the globe is covered with water and since rivers are abundant in most lands, why should there be any problem of securing enough water for our needs?

The answer is simple enough. *Water is never evenly distributed over the surface of the earth.* Some regions never get enough water in summer to nourish the food crops which in turn might nourish the people of those regions. In certain other places where rainfall is heavy, much of the rain runs down to the sea before it can do the crops any lasting good. It is more likely to bring floods than harvests.

"This is all too bad," you may say, "but nothing can be done about it. It rains when it rains, and man cannot change the workings of nature." It is true that man cannot turn the rain on and off to suit his needs, but he can do much to make the rain help him, as we have seen earlier in this chapter. He can also do much to make it harm him, as we shall see in the following paragraphs.

The Water in the Ground. When you think of the millions of springs and wells in this country alone, you realize that the water in the ground is a very important, though hidden, part of our natural wealth. Drought may come and ruin the crops of the farmer; but if the well that taps the underground source of water still flows, the farmer can somehow manage to live, and hope that next year will bring him better luck. If both the well and the crops dry up, the farmer must leave his farm.

Though the water in the ground depends on rain, it does not depend on *local* rain. The great dry plains of western



The underground water gives drink to man and to the surface waters of the ea

North America, for example, are well watered *underneath.* Much of the moisture that falls in the Rocky Mountains soaks into the rocks and moves eastward deep beneath the surface of the plains. So long as this great reservoir is filled, a steady supply of water may be had through wells, even though the surface of the earth in any particular spot is suffering from a drought.

All soil and rock, no matter how tightly put together, contain open spaces, or *pores.* Rain water soaks into the ground and then moves slowly along through the pores in a direction which is roughly parallel to the surface of the land. This water is known as the *ground* or *underground* water.

Almost every land surface in the world has water underneath it, though in some places this water is too deep to be of any use. In ordinary well-watered regions the top of the ground water (*water table*) is within fifty feet of the surface. Ground water actually comes to the surface in many springs, and in marshes, ponds, and rivers. It thus helps to keep the surface waters—and the vegetation that depends on them—from drying up. Study the drawing above, which shows the usual relationship between ground water and the surface of the land.

How You Can Help Conserve the Water Supply. Unfortunately the ground water is a treasure that can be, and has been, abused. In many places wells have run dry; the water table has sunk to alarming depths and with alarming speed. Indeed, the great hidden reservoir beneath North America shows unmistakable signs of drying up in many places. Why should this be, and what can be done about it?

Exercise. Interview some old settler in your region and see if he can recall a time when the water level stood nearer to the surface. See if he can remember any springs that are now dry or any other signs that would indicate a falling off in the supply of underground water.

As civilization has advanced, there has been more and more use of water for both home and industrial purposes. The average consumption of water in the United States is now just a little less than 130 gallons per person per day. This is a heavy drain on the national supply of both surface and underground water. Ordinarily, however, we seldom think of practicing water economy. Water for home use is still very cheap and in most places very abundant. We let it run out of our faucets and hoses with reckless waste.

When drought strikes a region, however, people realize the value of water. When water in wells and reservoirs runs low, conservation is practiced to avoid the serious inconvenience of a water famine. But we should not wait for a famine to practice conservation. We should always use plenty of water for our needs, but we should never waste it.

Exercise. Take stock of the amount of water you use for your daily personal needs. How much could you reduce your daily consumption without serious inconvenience?

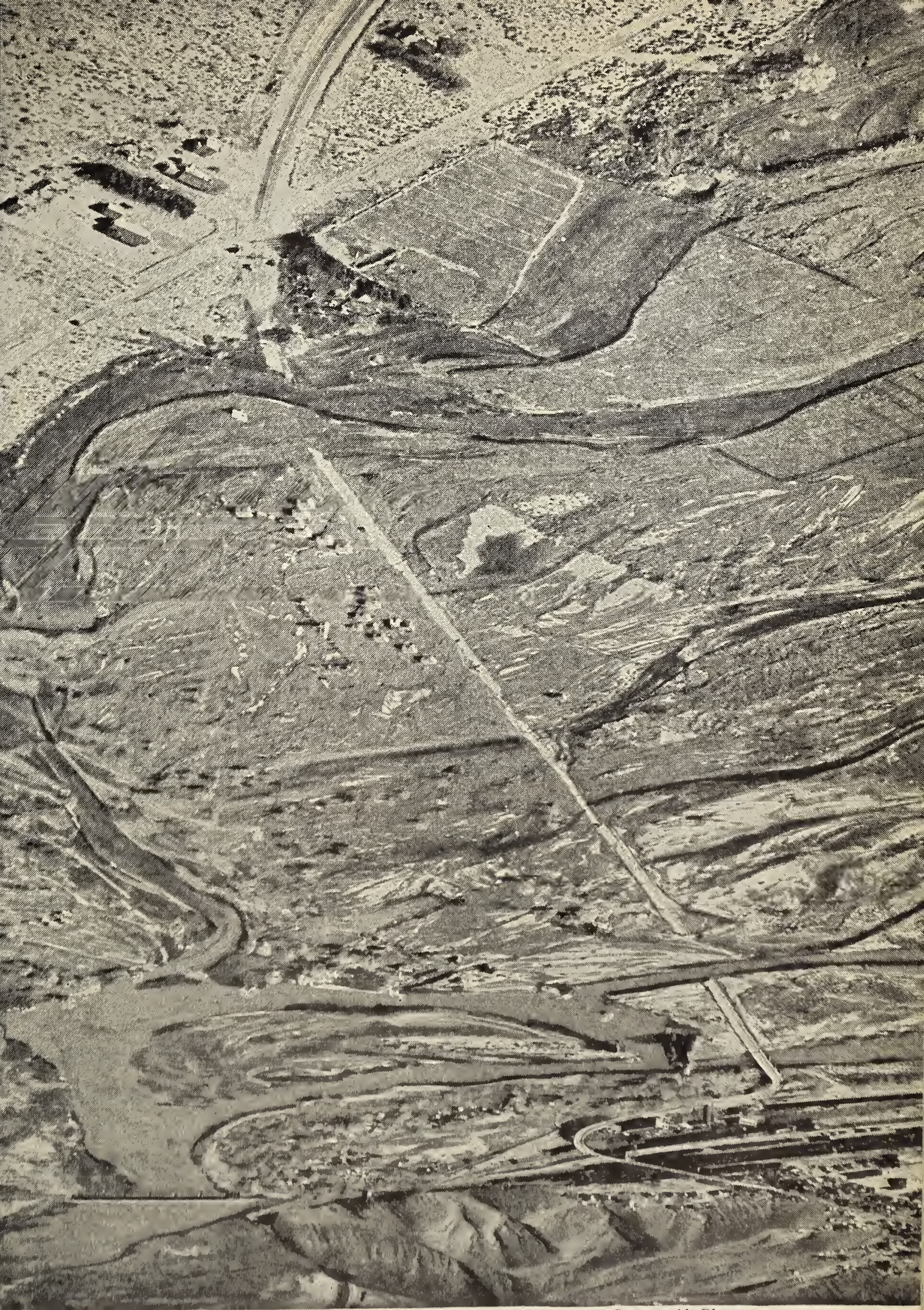
The Danger of Too Much Runoff. Only a small part of the damage done to our underground water supply has been due to the waste of water at the tap. The most serious damage has come as a result of the abuse of the surface of the land. Forests and grasslands have been widely attacked by the ax and the plow. Forest soil, with its covering of decaying leaves, and grasslands, with their tangled masses of roots, are giant sponges that soak up the rain as it falls. When the trees and the grasses are killed, the ground no longer can absorb the rains and the melting snows and feed them to the underground reservoirs. Water rushes down to the sea without sinking into the ground. Raging torrents, floods, falling water tables, and spreading deserts are the tragic results.

The rain and melted snow that run to the sea are called the *runoff*. If we are to avoid widespread water famine in the future, we must reduce the amount of runoff all over the country and increase the amount of water that soaks into the ground. How can this be done?

How to Reduce the Amount of Runoff. The only sure cure for any disease is the removal of the cause. The chief cause of water waste is the destruction of forests and grasslands; the cure is to bring back these natural guardians of the water supply. Fortunately the national government is aware of the seriousness of this problem and has taken steps to solve it.

Exercise. Ask your teacher to write to your senator for literature that explains what the government has done to protect the general water supply of your state. After studying this literature, make a report to your class on "Conservation of Water in Our State."

Individuals can do much to help make the rain water stay where it falls until a great deal of it soaks into the



Spencer Air Photo

e of the strange perils of desert lands is too much water. With little vegetation to w down the runoff, the occasional heavy rainstorm may do great damage. Notice at happened to a small desert waterway and the country around it after a violent cloudburst had struck ground. The farmer, in particular, can see that sloping land is covered with vegetation which will slow down the runoff. He can see that close-growing crops, such as wheat, oats, and hay, are planted in places where the runoff is severe. Anybody can plant a tree in a place where water runs over the ground when it rains. If everybody did this, the problem of water conservation would be more than half solved.

Exercise. Make a survey of your neighborhood during or just after a rain, and report to your class on runoff conditions. If the runoff is fast and severe in any place, see if you can discover the cause as well as some possible cure.

The Importance of Water. So we come to the end of our exploration in the world of water. We have discovered the tremendous importance of water in our lives. Indeed, if all water should suddenly go out of our lives, all life would just as suddenly go out of us.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The greatest service of water to man is irrigation.

2. Man's use of water power is no better developed now than it was a thousand years ago.

3. Water is a good source of power, but it is much more expensive than other sources of power.

4. A sluggish stream is better for water power than a fast-moving stream because it can be more easily harnessed and controlled.

5. Some streams which are otherwise suitable for the development of water power cannot be used for that purpose because they are full of rapids.

6. Rivers that flow out of lakes are no good for water power because the lakes slow down the speed of the water.

7. Niagara Falls is too powerful ever to be harnessed to a water-power plant.

8. Nearly all the possible water power in the United States is now developed.

9. Deserts would be too hot for plant life even if they could be watered by irrigation.

10. Land at the foot of a mountain range does not have to be irrigated because rain falls abundantly on mountains and flows down in streams to the land below.

11. Irrigated farms have a hard time competing with farms that do not have to pay for water.

12. Important seaports have grown up around all the best harbors of the world.

13. Because water is fairly evenly distributed over the earth, the conservation of water is nowhere a serious problem.

14. The greatest damage to our water supply is the waste of water in homes and factories.

Questions for Discussion

1. Perhaps there is a lake or a stream near your home town that has not been put to work. Discuss the possibilities of putting it to work.

2. Perhaps there is water near your home town that *has* been put to work. Discuss the effects of this on the growth of the town and on the work of its people.

3. Much of the public work undertaken by the government in recent years has been an attempt to make water work for us. Can you name any of these work projects? Do they seem worth while? Do they help to conserve or to waste the supply of water?

Things to Do

1. Carefully study a relief map and a rainfall map of the world. What country seems to have the greatest wealth of water power? Has that country developed this wealth to a large or a small degree?

2. Compare the rivers of New England with the rivers of Georgia. In which locality are the rivers more suited to the development of water power? In which locality are the rivers more suited to navigation?

3. Ask your librarian to help you find some reading matter about the power plant at Niagara Falls. Prepare a report on it for your class.

4. At Grand Coulee, Washington, the United States government is undertaking one of the greatest water-power and irrigation projects in the history of civilization. Ask your teacher to help you find information about it and then make a report to your class.

5. Make a "Dam and Reservoir" scrapbook. Collect pictures and news items about new water-power and irrigation developments. You will be surprised at how rapidly your scrapbook grows.

6. Look up descriptions of the four greatest seaports in the United States. Make lists of the chief advantages of each of these seaports, and compare the lists. Try to determine why the greatest seaport was able to become the greatest.

7. Get an outline map of North America. With differently colored crayons draw in the main inland waterways. Find out something about each one, and arrange this information in a chart to go with the map.

8. Read Mark Twain's *Life on the Mississippi* and Emil Ludwig's *The Nile*. These are two of the best books ever written on rivers. Do not be discouraged because *The Nile* is a large, heavy book. It is also a fascinating book, whether you read it all or merely "dip into it." These two books will show you how rivers can affect the lives of the people who live on their banks.

9. Write a report on all the ways in which water works for you personally and read it to your class.

10. Examine the depth at which water stands in the wells of your neighborhood and thus get a mental picture of the water table. Try to find out if the water table is sinking and if so, why.

UNIT THREE

THE WORLD
OF
AIR

EXPLORING THE WORLD OF AIR

Have you ever realized that we live like fish in an ocean—the vast but invisible ocean of the air?

◆

Have you ever realized that the ocean of air, like an ocean of water, has its own special behavior?

◆

Have you ever wondered what air really is and what it does?

◆

In Unit Three of this book we are going to explore the mysteries of the air.

◆

We are going to try to learn about a great invisible world.

◆

All who enjoy exploring are invited to go along.

CHAPTER SEVEN

How Does Air Behave?

WHERE WE FIND AIR

What All of Us Know about Air. We all know that air exists, even though we cannot see it. We know that we breathe it into our lungs several times each minute of our lives. We know that both animals and plants would quickly die without it. We know that it cools us when it brushes our cheeks in a summer breeze, and that it makes our eyes water when it strikes them in a wintry blast. We know that it can blow off hats, slam doors, and sometimes rip whole towns to pieces.

How to Explore the Air. How can we know these things about air when we cannot see it? *We can know them because we can know the effects of air, though air itself is invisible.* This gives us a clue as to how we might learn a great deal more about air. By carefully observing the effects of air on objects which we can see, we can learn a great deal about how air behaves.

The Air around Us. We know that many people have lived for many years on every continent of the earth. We know that a few people have reached the poles of the earth, and have returned to tell their stories. We know that men have sailed to every corner of the sea. None of these things could have happened if there were places on earth where air did not exist. We can therefore be sure that *air surrounds the earth as completely as the skin surrounds an apple.*

We also know from our studies in Chapter III that air is dissolved in the waters of the earth. If you do not remember the experiments we performed to prove this, turn back to page 64 and perform them again.

Is there any nook or cranny in the world where there is no air? Is there air, for example, in the soil or in a piece of wood? Two simple experiments will answer these questions.

Exercises. How to prove that there is air in soil: Pour some loose soil into a drinking glass until it is half full. Slowly pour water over the soil until the glass is almost full. What proof do you get of the presence or absence of air in the soil?

How to prove that there is air in wood: Tie a weight to a piece of unpainted wood and sink it in a vessel of water. Warm the water but do not let it boil. What proof do you get of the presence or absence of air in the wood?

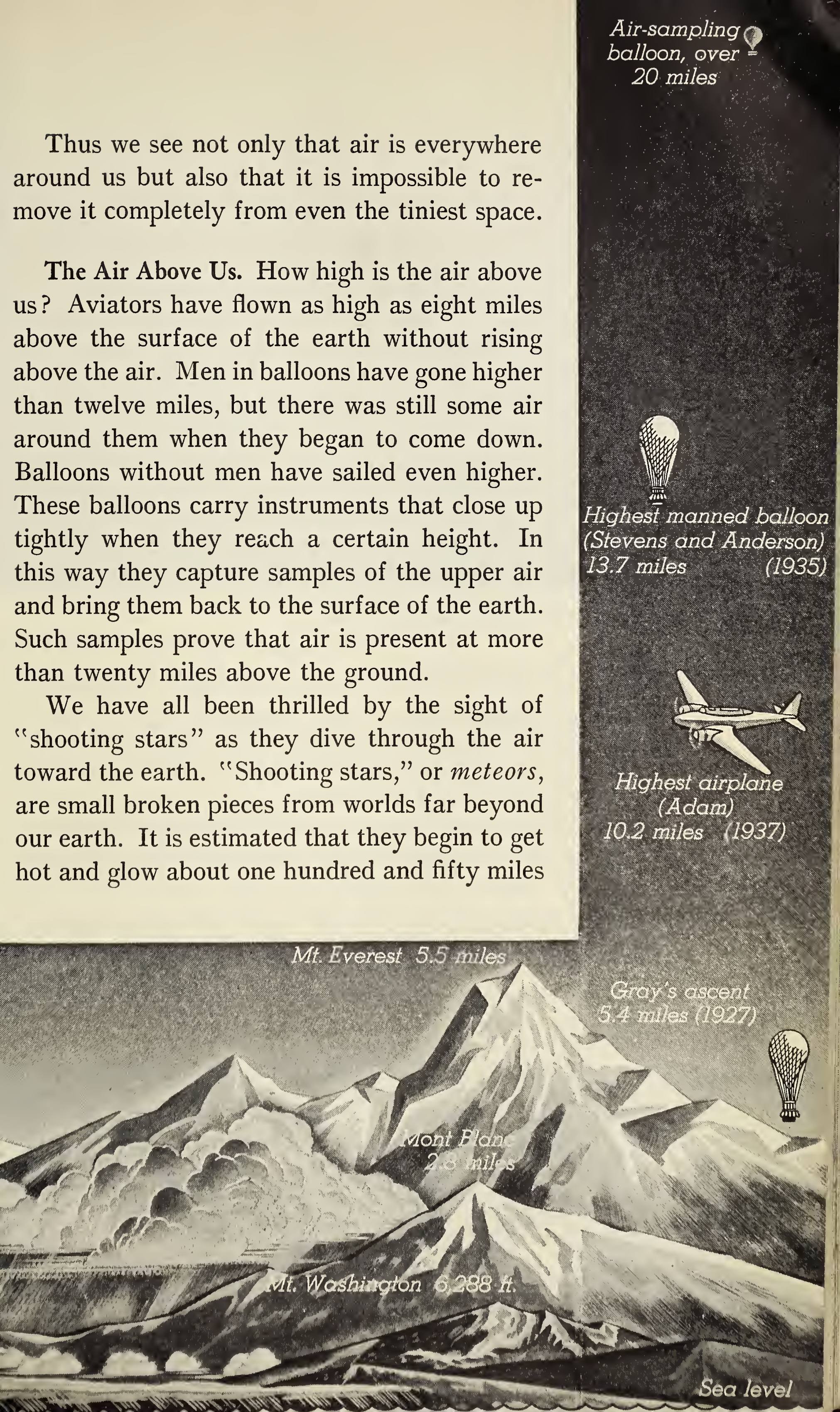
It would seem from these experiments that air is almost everywhere. We know that air is present even in a box or a bottle that we call empty. When we say that a thing is empty, we really mean that it contains nothing but air.

If the air could be taken out of a bottle so that nothing at all was left there, the space would be a *vacuum*. No one, however, has ever been able to make a perfect vacuum. A *partial vacuum* is all that anyone can make. We can pump nearly all the air from a container, but a little air will stay there no matter what we do. We use "vacuum tubes" in our radio receiving sets, but even the best of these contain some air. Certain old-fashioned electric-light bulbs were called "vacuum bulbs," but these too contained some air.

Thus we see not only that air is everywhere around us but also that it is impossible to remove it completely from even the tiniest space.

The Air Above Us. How high is the air above us? Aviators have flown as high as eight miles above the surface of the earth without rising above the air. Men in balloons have gone higher than twelve miles, but there was still some air around them when they began to come down. Balloons without men have sailed even higher. These balloons carry instruments that close up tightly when they reach a certain height. In this way they capture samples of the upper air and bring them back to the surface of the earth. Such samples prove that air is present at more than twenty miles above the ground.

We have all been thrilled by the sight of "shooting stars" as they dive through the air toward the earth. "Shooting stars," or *meteors*, are small broken pieces from worlds far beyond our earth. It is estimated that they begin to get hot and glow about one hundred and fifty miles


Air-sampling balloon, over 20 miles
Highest manned balloon (Stevens and Anderson) 13.7 miles (1935)
Highest airplane (Adam) 10.2 miles (1937)
Mt. Everest 5.5 miles
Gray's ascent 5.4 miles (1927)
Mont Blanc 2.8 miles
Mt. Washington 6,288 ft.
Sea level

Yerkes Observatory

The death of a meteor. Most meteors burn up when they strike the air that surrounds the ea

above the ground. They cannot begin to glow until they strike the air which surrounds the earth. (In the next chapter we shall learn why this is so.)

The white streak you see on the photograph above is the track of a burning meteor which was photographed while the meteor was rushing through the upper air. It shows that there is enough air high above the surface of the earth to make the meteor white hot.

AIR IS A VERY REAL THING

Air Occupies Space. Though we live at the bottom of an ocean of air, we do not always realize it. Air is so light and transparent that we generally do not notice it. It nevertheless is a very real thing. It occupies space, has weight, and exerts pressure.

AIR IS A VERY REAL THING

While washing dishes have you ever pushed a milk bottle quickly into the water and noticed bubbles escaping from it? The water splatters and the bottle slowly fills. If you know that air occupies space, it is easy enough to explain this common happening. The "empty" bottle is full of air. When you put it into the pan of water, the air is forced out of the bottle as the heavier water enters. The bubbles you see are bubbles of air.

Exercises. To prove that air occupies space: Turn a clean drinking glass upside down and push it into a bowl about half full of water, as shown at 1 in the diagram below. Does any water enter the drinking glass? Why doesn't the glass fill with water?

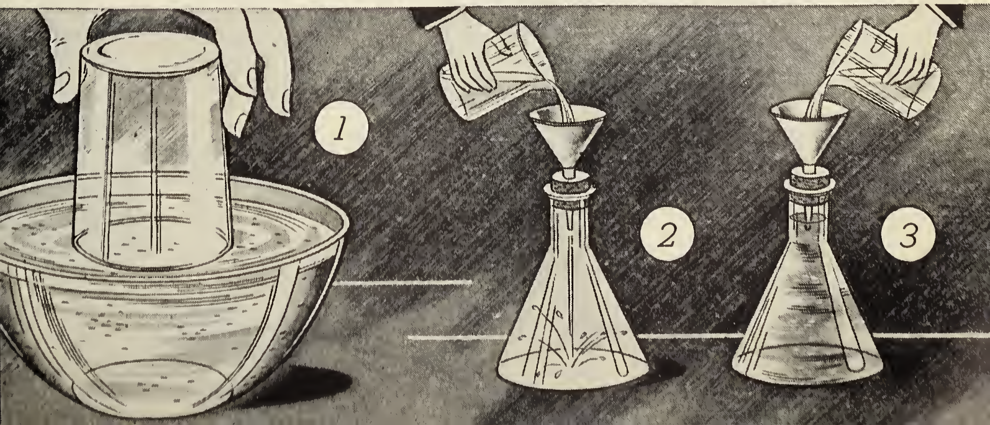
Place a funnel through a stopper and fit it into a bottle, as shown at 2. Pour water into the funnel. Explain what happens.

Arrange the funnel as shown at 3. Notice that the end of the funnel is beneath the water. Why doesn't water run into the neck of the bottle? Remove the stopper. Now does the water run in? Why?

Hold your finger tightly over the end of the tube of a bicycle pump, as shown on page 166. Try to push down the handle of the pump. Why doesn't it go down?

Did you ever blow up a paper bag as the girl on page 166 has done, and then "pop" it with your hand? If you did,

Through these experiments you can prove that air occupies space



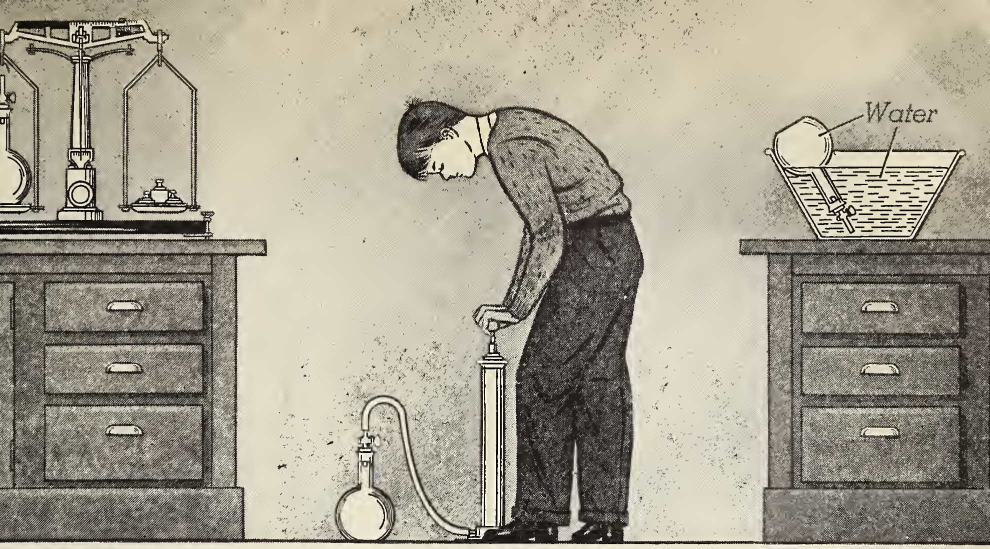
you know the bag felt as if it were filled with something. That something was air. The pop you heard was caused by the rush of air from the bag when it broke. This common trick is only one illustration of the fact that air occupies space. There are many other illustrations.

Exercise. What other illustrations can you find to prove that air occupies space?

Air Has Weight. We have said that air is a very real thing. It not only occupies space but it also has weight. Ordinarily we don't think of air as having weight. If we compare the weight of air with the weight of water or stone, air does not seem to be very heavy. But it does weigh something, and you can prove it.

Exercises. How to prove that air has weight: Obtain a small air pump, a flask with a rubber stopper, and a glass tube with a valve, as shown on page 167. Weigh the flask with stopper, tube, and valve. Now pump air from the flask with the air pump. Close the valve in the glass tube and weigh the flask and fittings again. Do you find that the flask weighs more or less after the air has been removed? Does air have weight?

How to prove that air was removed from the flask: After you have weighed the flask for the second time, put the end of the tube in water as shown. While it is under water, open the valve. Explain what happens.



This boy is proving that air has weight

When the experiment just described was carried out in one classroom, the flask nearly filled with water. That meant that nearly all the air had been pumped out.

If you were to weigh one cubic foot of air, you would find that it weighed about 1¼ ounces. One cubic foot of water weighs 1000 ounces. Thus water is about eight hundred times heavier than air. *Yet light though it is when compared with an equal volume of water, air is surprisingly heavy in large quantities.* Scientists have estimated that all the air in the world weighs 5 quadrillion (5,000,000,000,000,000) tons!

The Wind. Wind is merely moving air. We need only watch a sailboat or a windmill being driven by the wind to know that air has weight. The picture on page 168 shows what air can do when the wind runs wild. It shows that air is not only very real but also very powerful.

THE PRESSURE OF AIR

Air Pressure. At sea level the weight of the air above each square inch of the earth's surface is about 15 pounds.

Blackington

Houses may be broken into splinters when the air runs wild

Notice that this is the weight of air at sea level. This is important because a cubic foot of air does not always weigh the same amount. As you will learn later, air at altitudes high above the surface of the earth weighs less than air at sea level. The weight of air also changes as it is heated or compressed.

The weight of the air over one single square foot (144 square inches) of the earth at sea level is 144 times 15 pounds, or 2160 pounds. This is about the weight of a small automobile. If you think of the vast number of square feet in the entire surface of the earth—each square foot bearing the weight of more than a ton of air—you can understand why the weight of all the air runs into quadrillions of tons. *The pressure produced by this weight of air on the surface of the earth is known as the air pressure.*

Why the Air Does Not Crush Us. Air exerts an equal pressure on all parts of our bodies. It surrounds us and presses upon us just as water surrounds and presses upon a fish. At 400 feet beneath the surface, the pressure of water on every square inch of a fish's body is about 170 pounds. Why doesn't the fish collapse? It doesn't collapse because the water pressure is equally distributed through the cells of its body. The pressure from the inside of the fish is equal to the pressure on the outside.

The surface of a human body of average size contains about 2000 square inches. Since the air pressure is about 15 pounds per square inch, the total pressure on each average-sized man or woman is about 30,000 pounds! This pressure of the air does not crush us any more than the pressure of the water crushes a fish. Let us see exactly why.

Air enters the body through the lungs and is distributed by means of the blood to every cell of the body. *The pres-*

air pressure on your body is just about equal to the weight of this heavily loaded truck

sure on the inside of the body is thus made equal to the pressure on the outside. Unless this exact balance between the inside and the outside pressure is disturbed, we are hardly conscious of air pressure at all. The balance is disturbed only when the pressure outside our bodies is increased (as in deep-sea diving) or decreased (as in mountain-climbing or in high-altitude flights in airplanes or balloons). In such cases we immediately become conscious of air pressure.

People who climb high mountains often suffer from nosebleed. At a high altitude the pressure outside the body is less than at a low altitude because the higher we rise in the air the less air there is to press upon us. The result of this is that at a high altitude the air pressure outside the body becomes for a time somewhat less than the air pressure inside the body. This difference in pressure may cause the small, weak blood vessels in the nose to break before the balance of pressure is restored.

How to Measure the Pressure of Air. There are many ways of demonstrating air pressure. A simple method is shown in the photograph on the opposite page.

Exercise. How to demonstrate the pressure of air: Fill a bottle with water and place it open end down in a dish of water. Does the water stay in or run out of the bottle? Why?

The downward push of the air on the surface of the water in the dish was greater than the downward push of the water in the bottle. The water in the bottle was held up, or balanced, by the air that pressed on the water in the dish. How tall a column of water do you suppose air can support?

This girl is demonstrating the pressure of air

Many years ago, when scientists first became interested in air pressure, a German scientist, Otto von Guericke, tried to find the answer to that question. He was already familiar with the facts which you have just learned. After many experiments he set up a tube, 36 feet tall, which, except for an upper end of glass, was made of brass. The lower end was open, and the upper end of glass was closed. The tube was filled with water and turned upside down in a tub of water outside the house. It reached from cellar to attic. The height of the water in the tube remained between 30 and 34 feet, differing a little from one day to another, but never rising to the top of the tube and never falling lower than about 30 feet.

On the surface of the water inside the tube, which was about level with an upstairs window, floated a cork image of a man. Because of changes in the pressure of the air from day to day, the little cork man moved up and down in the tube. The ignorant people of the village gathered round to watch the performance, thinking they were seeing magic (see the drawing on the opposite page).

Since Von Guericke's day several kinds of instruments have been invented for measuring the changes in air pressure. They are called *barometers*. The word "barometer" comes from two Greek words meaning "weight" and "to measure." Barometers are well named, because they really "measure" the "weight" of the air.

Warm Air and Cool Air. Most differences in the pressure of the air are due to the fact that some of the air is warm and some is cool. A definite quantity of warm air presses less heavily upon the surface of the earth than an equal quantity of cool air, because *warm air is lighter than cool air*. Let us see if we can prove that statement.

Exercises. How to prove that warm air is lighter than cool air: Use a clean, dry flask as you did in the experiment on page 166. Use the same rubber stopper and the glass tube with a valve in it. Weigh the flask and fittings just as you did before. Now open the valve and heat the flask until it is very hot. Close the valve and stop heating the flask. Weigh it again. Does it weigh more or less than when it was cool? After the flask has cooled, open the valve. Weigh the flask again. What has happened? Can you explain this?

Can you think of any other ways of discovering that warm air is lighter than cool air?

What Makes the Wind Blow. When you realize that warm air is lighter than cool air, you can understand certain common things that you may not have understood before.

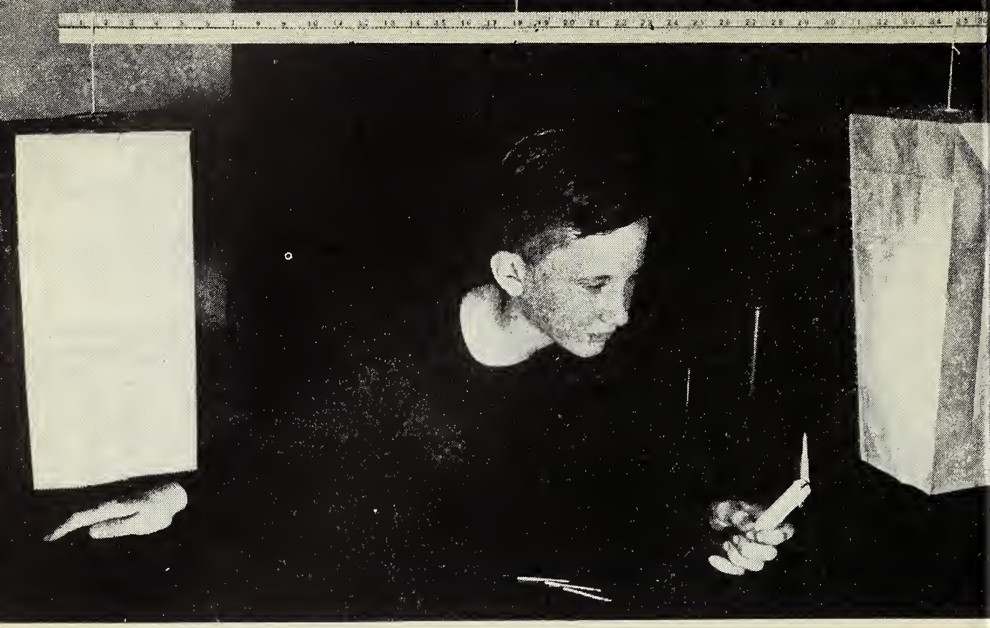
Among other things, you can understand what makes the wind blow. Some time or other we all have wondered about the wind. What makes the air so restless? What makes it rush along at times so fast and with so much force? What makes the draft you feel in the schoolroom when someone opens a window?

Before you try to answer these questions see how much you can learn from just looking about you. If you hold your hand a few inches above a hot radiator, you will find not only that the air above the radiator is warmer than the air in the rest of the room, but also that it seems to press against your hand. As a matter of fact the *air over the radiator is rising because it is warmer and therefore lighter than other air in the room.*

Outdoors the air is doing much the same thing. Some of the air at the surface of the earth gets heated. It becomes lighter and is forced upward by the colder and heavier air around it. The heavier air moves in to take the place of the lighter air. This process continues, with lighter air ever rising and heavier air ever moving in, getting warmed, and then rising in its turn. The result is wind.

EXPLORING THE OCEAN OF AIR

The Fire Balloon. Have you ever heard of a "fire balloon"? Very likely you have not, because the fire balloon is almost unknown today. In the old days, however, it was the chief attraction of every country fair. The fire balloon was merely a large cloth bag with an opening at the bottom. A fire was built below the opening so that warm air rose and collected in the bag above. Because warm air is lighter than cool air, the balloon grew fatter and lighter until finally it was able to rise from the ground.



You can show how the fire balloon rose by this experiment in the classroom

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Exercise. Tie a string to the middle of a straight stick which is about three feet long. Hang up the stick by the string so that it may swing freely without touching anything. Tie two more strings to the ends of the stick. Attach to the strings by gummed stickers two paper bags of the same size and weight, upside down as shown above. Open each bag as far as possible and balance it on the stick. Hold a lighted candle below one of the bags. (Do not let the bag catch fire.) What happens?

What caused the bag in the experiment, and the balloons which it resembled, to rise? The answer is simple. Filled with warm air, they became lighter than equal volumes of cool air. Being lighter, they were pushed up by the heavier air around them.

The fire balloon floats in air for the same reason that a boat floats on water, because, cubic inch for cubic inch, it is lighter than the material that supports it. The balloon rises as long as its weight is less than the weight of a similar volume of air. It falls when its weight becomes greater than the weight of a similar volume of air.

Modern Balloons. A modern balloon is usually a large, rubber-lined bag filled with some gas which is lighter than air. There are several fairly common gases which are lighter than cold air, and which rise without being heated. By using such gases in balloons instead of heated air, the old nuisance of keeping a fire burning is avoided.

Hydrogen, for example, is a gas which is only $\frac{1}{14}$ as heavy as air. Helium is another light gas, about $\frac{1}{7}$ as heavy as air. Hydrogen can be produced quite easily in the laboratory. Helium, though generally rare, is found in the rocks of certain localities, and may be taken from the ground by drilling.

Hydrogen and helium are frequently used in modern balloons and gas-supported airships. Hydrogen is very much lighter than helium, and its lifting power is therefore very much greater. It is also cheaper to produce than helium. Unfortunately, it explodes very easily. The terrible tragedies which hydrogen has caused will doubtless greatly reduce its use in the airships of the future. Helium, which cannot burn, will most likely largely replace it.

The Thrilling Flight of Captain Gray. One of the early pioneers in ballooning to high altitudes was Captain H. C. Gray of the United States Army Air Corps. His own story of a flight to a new record of 42,470 feet illustrates many of the facts you have learned about air and air pressure. Preparations for the flight were carefully made. From the knowledge gained in previous explorations Captain Gray knew that at the height he was attempting

Acme

Here is the reason why hydrogen gas should never be used in airships

to reach he would find it extremely cold. Since he was riding in an open basket, he bundled himself in furs and woolen clothing. These were not very comfortable in the warm weather on the ground, but he knew he would need them later.

He also knew that the air at high altitudes is extremely "thin." He knew that this air has too little oxygen for breathing, so he took along tanks of oxygen and a mask through which he might breathe it. He also hung bags of sand on the outside of the basket. These bags had special attachments by means of which the sand could be let out.

As soon as the balloon left the ground, Captain Gray began to let the sand run out. This steadily reduced the weight of the balloon, and it steadily rose in the air. At about 12,000 feet Captain Gray began to notice some difficulty in breathing. At 18,500 feet he put on the oxygen mask and used it from that point on.

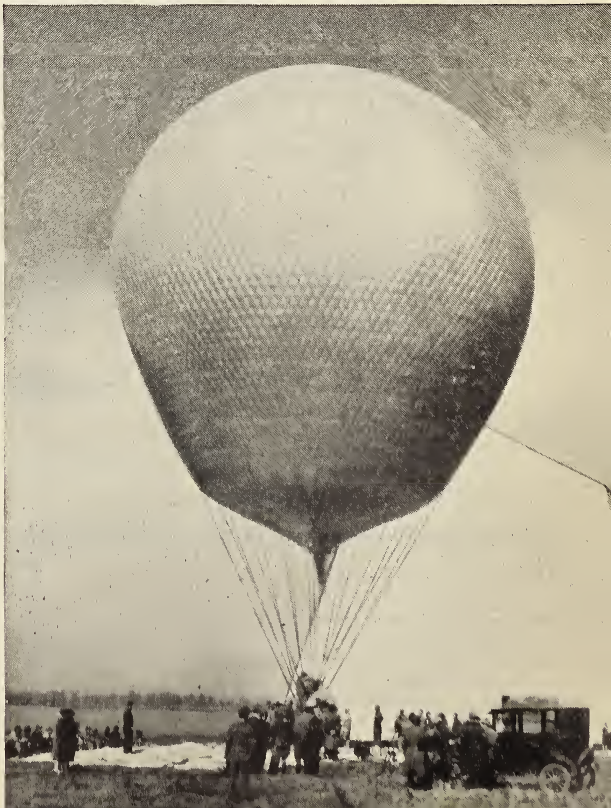
As he rose higher and higher, the air grew colder and colder. He put on warm gloves and bundled up as tightly as possible in his heavy clothing. Soon the moisture from his breath began to freeze on his goggles, and he found it difficult to see. Still the balloon rose. At 40,000 feet it stopped. The sand bags were empty and it was plain to Captain Gray that if he were to break the altitude record of about 41,000 feet, he would have to throw something else overboard to lighten the balloon. So he tossed out an oxygen tank. The balloon began to climb again.

Finally, at what Captain Gray thought was a record height, he decided to come down. By now the bag of the balloon had puffed up enormously because the air pressure outside was too weak to hold it to its original size.

Captain Gray opened the gas valve, and as gas was released the bag began to shrink and the balloon began to descend. It had climbed at a rate of 500 to 800 feet a minute, but it was now falling between 1400 to 1900

The balloon that gave Captain Gray an altitude record and a scare

U. S. Army Air Corps



feet a minute. Plainly something would have to be done to slow down this speed before the surface of the earth was reached.

Desperately Captain Gray threw overboard all his remaining equipment, including empty sand bags, oxygen tanks, and radio batteries; but still the balloon plunged madly toward the ground. Finally, at a height of 8000 feet, the frightened balloonist climbed to the rim of the basket and jumped. His parachute opened, and he floated safely to earth, landing more than one hundred miles from his starting point. The flight had taken about an hour and a half. Auguste Piccard and others have since made higher flights in balloons. But no one has ever made a more thrilling one.

The Behavior of Air. So in one way or another we can explore the invisible air by studying what it does to visible things. In this chapter we have learned something about how air behaves. We have proved that it occupies space, has weight, exerts pressure, and supports objects lighter than itself. But what exactly is it? In the next chapter we shall try to answer this question.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Aviators have discovered "pockets" in the air which are perfect vacuums.
2. Wood is too tightly made to contain any air.
3. Radio would have been impossible if inventors had not discovered a way of drawing all the air from a glass tube.

4. As far as we know, the air is only a thin film on the earth, about twenty miles thick.

5. The great mystery of air is that it has weight but does not occupy space.

6. The air in an average-sized room is so light that it cannot be weighed by any method known to science.

7. A cubic foot of air in London weighs less than a cubic foot of air at the top of Mt. Everest.

8. The air above us does not crush us because it does not weigh enough.

9. In any given place the pressure of the air is always the same.

10. Warm air is heavier than cool air.

11. Wind is caused by the rush of heavy warm air to fill the place left vacant by light cool air as it rises.

12. Helium is a better gas for balloons than hydrogen because it is much lighter.

Questions for Discussion

1. If our earth were only half as large as it is, how do you suppose the air would be different in amount, weight, and pressure from what it is? How would this affect our bodies and our activities?

2. When a can of condensed milk is opened, two holes are ordinarily punched in the top, one near the center and the other near the edge. Why?

Things to Do

1. Make a collection of pictures which will show the power of wind.

2. Look up some stories of mountain-climbing. List all

the difficulties the climbers met which seem to have been caused by low air pressure at high altitudes. Some of the most thrilling stories of this kind tell of attempts to climb Mt. Everest, the highest mountain on earth.

3. "Suck" some water through a straw and explain exactly what you have done.

4. Study a fountain pen and try to explain how it works.

5. Study a "vacuum" cleaner and try to explain how it works. Why is it called a vacuum cleaner?

6. Make a list of all the ways you can think of by which men make air pressure work for them.

7. Prepare a booklet or poster to show the development of balloons from the earliest days to the present time. Get pictures for illustrations or else make drawings from illustrations in books and magazines.

8. The story of the discovery, preparation, and use of helium is very interesting. Prepare a report on this gas and illustrate with pictures or sketches.

CHAPTER EIGHT

What Is Air?

AIR IS A MIXTURE OF GASES

What a Mixture Is. Who has never been in the kitchen while Mother was baking a cake? We trust that no reader of this book has had the bad luck to miss that delightful experience. Perhaps, however, it has never occurred to you that while waiting impatiently to "lick the pan" you might make a few scientific observations. Among other things, you might learn what a mixture is.

A cake is a typical mixture. It is made of sugar, butter, eggs, flour, milk, baking powder, and flavoring. All these different things are stirred together into a soft pasty mass, which becomes firm when baked in the oven.

In the finished cake we cannot clearly recognize by look or taste any one of the things that went into it. We see and taste a blend of them all. Yet if we put a bit of cake under a microscope, we might be able to see little specks of the flour, sugar, butter, and other things out of which it was made. These things are not so closely united in the cake that we cannot still recognize them under the microscope, even though we fail to do so with our unaided eyes.

Any close mingling of materials which is yet not close enough to destroy completely the individual qualities of the materials which have mingled is called a mixture.

Air Is Like Cake. Air, like cake, is a mixture. It seems like a single material; but when we study it carefully, we find it a blend of several different materials. Unlike cake,—which is a mixture of solids, liquids, and gases,—air is almost entirely a mixture of gases. All these gases are invisible. We cannot look at air, as we look at cake, through a microscope. How, then, can we learn about the different gases of which it is made?

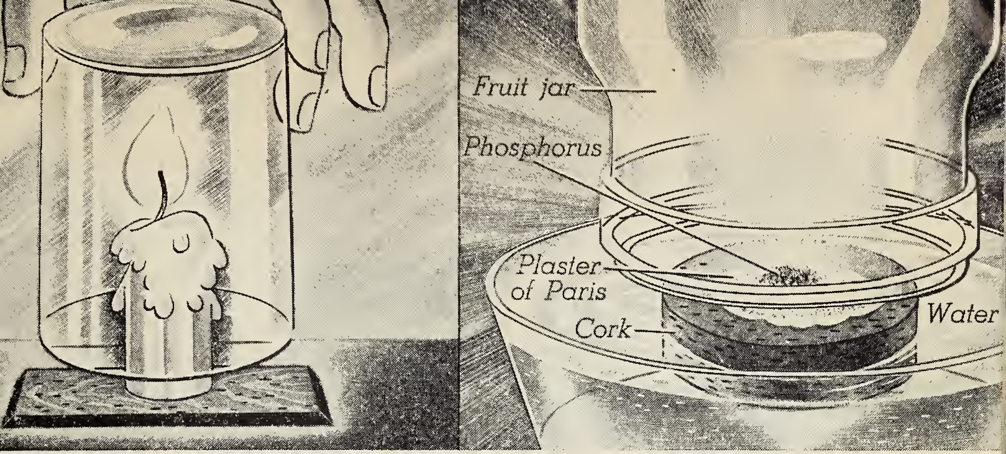
You will remember that in the last chapter we learned how air as a whole behaves by studying its effects on things we can see. We can learn about the separate gases of the air in the same way. But to do so we must sharpen our wits and become detectives. We must follow every clue.

LEARNING ABOUT AIR THROUGH FIRE

The Lively Gas. One gas in the air is more important to us and to the world at large than all the other gases com-

A cake is a typical mixture

Roberts



With this equipment you can prove that air is necessary for burning

bined. That gas is oxygen. Although only 21 per cent of the air is oxygen, the world would be a very different sort of place if oxygen did not exist. This gas is so important because it is so lively.

As we have seen in Chapter III, oxygen enters the blood of living creatures, and by doing so makes life possible. In a later unit we shall see how it also enters the flesh of dead creatures, and by doing so makes decay possible. It also combines with many kinds of rock and soil, and by doing so changes the surface of the earth. But the liveliest thing that oxygen does is to unite with such things as wood or paper, and by doing so to make them burn.

On the Trail of Oxygen. Fire is the most exciting effect of the lively behavior of oxygen. It is also the best means of learning what oxygen really is. The trail to the understanding of oxygen is a trail of fire.

Exercises. How to prove that air is necessary for burning: Place a short candle on end and light it. Cover the burning candle with a drinking glass, as shown in the drawing above. What happens? How long does it take for the effect to occur? Can you account for it?

For a second experiment you will need a flat cork at least two inches across and not over a half inch thick. Make a little hollow in the cork not less than an inch across. Fill the hollow with plaster of Paris, as shown in the drawing on page 185. Allow the plaster to set. Float the cup, plaster up, in a dish of water. Place a small amount of red phosphorus on the plaster and set it afire with a match. Turn a fruit jar over the cork with its edge under the water. Observe what takes place inside. How long does the phosphorus burn? What differences do you notice between the burning of the phosphorus and the burning of the candle in the previous experiment?

The natural conclusion from these two experiments is that air is needed for burning. But we must remember that air is a mixture of several different gases. Are all these gases necessary for burning? If all are necessary, we should expect to find that when the candle or the phosphorus stopped burning, all the air under the glass and the fruit jar had been used up. This, however, was not so.

Look closely at the jar under which you burned the phosphorus. You will notice that the water has risen in it to a level higher than the level of the water in the dish. The reason for this is that part of the air in the jar has been used in burning the phosphorus. The pressure of the air outside the jar has forced water from the shallow dish into the jar to replace the air which has been used in burning.

Since the water does not completely fill the jar, you can be sure that there is still "air" left in the jar even after burning has stopped. But it is not the same kind of air that was there in the beginning. If you could examine this air carefully, you would find one very important difference. You would find that some of the oxygen has disappeared.

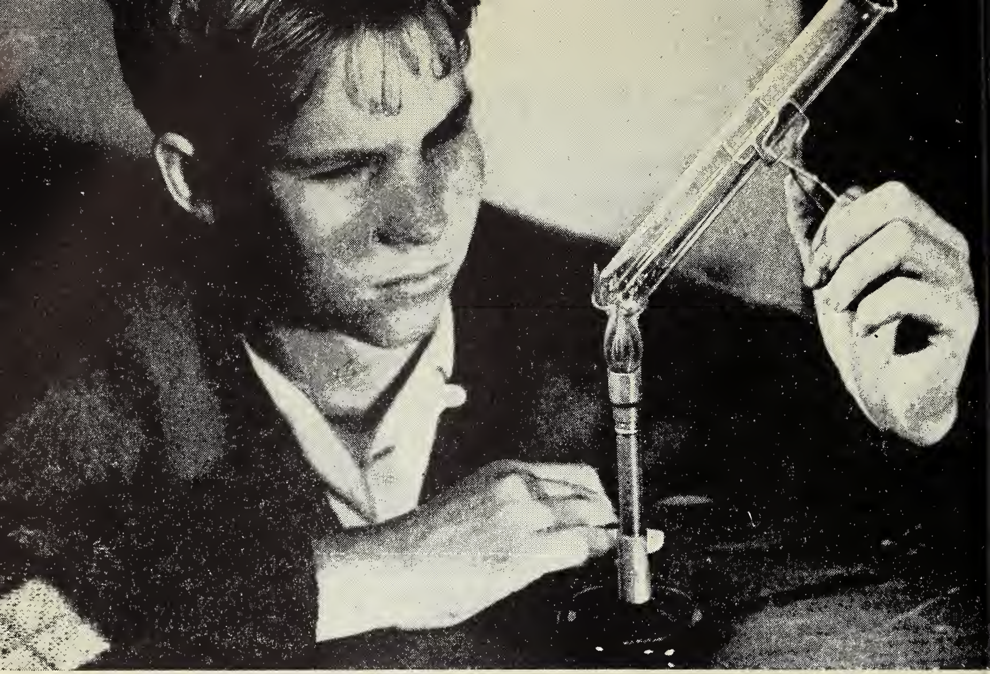
In other words, some of the oxygen was used up during the burning of the phosphorus. The correct conclusion from our experiments, therefore, is that *oxygen in particular, rather than air in general, is necessary for burning*. The other gases of the air take no part at all in the process.

Do you see now why the candle and the phosphorus stopped burning when you covered them with glass? You shut off the supply of oxygen in the outside air. The candle went out when about one fourth of the oxygen under the drinking glass had been used. The phosphorus burned more vigorously, but in time it too went out—when nearly all the oxygen under the fruit jar had been used.

If There Were Less Oxygen in the Air. Scientists have estimated that if air contained 16 instead of 21 per cent of oxygen, neither wood nor coal would burn. Indeed, if the oxygen in the air were only 1 per cent less than it is, things would burn less easily than they do. Keeping warm in winter would be a greater problem for us than it now is.

If There Were More Oxygen in the Air. If the amount of oxygen in the air were greater than 21 per cent, that too would change conditions on earth. A few experiments with pure oxygen will show you why.

Exercises. How to make pure oxygen: Get some potassium chlorate and some manganese dioxide, materials which are rich in oxygen. Mix *without grinding* a teaspoonful of the potassium chlorate with a quarter teaspoonful of the manganese dioxide, and then place the mixture in the bottom of a test tube. Heat the powder, as shown on page 188. The test tube will soon be full of pure oxygen released from the powder by the heat.



With this equipment you can show the effects of pure oxygen on burning

How to show that things burn better in pure oxygen than in air: Light a splinter of wood and push it into a test tube full of oxygen. If there is any glow at the end of the splinter, it will burst into flame when pushed into the pure oxygen. Great care should be taken against getting burned yourself while doing this experiment.

Next get a piece of braided picture wire, about ten inches long. Unravel about half an inch of the wire and stick a little tuft of cotton on the unraveled end. Set fire to the cotton and quickly lower it into a test tube of air. Does the cotton burn? Does the wire burn? Now do the same experiment with a test tube full of pure oxygen. The cotton should burn brightly and quickly. A shower of sparks from the end of the wire will show that the iron also burns. Here again, be very careful!

It is clear from these experiments that fire would be very difficult to control if there were more oxygen in the air than there actually is. If the percentage of oxygen in the air were to increase as little as 5 per cent, a forest fire, for example, would be much more difficult to put out.

THE CANDLE AND THE FLAME

How a Candle Burns. Let us next observe carefully what happens when a paraffin candle is lighted and allowed to burn unhindered.

Exercise. Touch the wick of a candle with a lighted match. Does the wick burn at once with a full-sized flame, or does it take a little time to get started? After it has burned for a short time, look for melted paraffin around the wick. Is the wick soaked with liquid paraffin? Blow out the flame. Do you see "smoke" rising from the wick? This smoke is largely paraffin which has taken the form of gas. Light the candle again. What causes the flame? Is it the wick or the paraffin that is burning?

The above observations show that when you bring a match to a candlewick, you must hold it there a short time before the candle starts to burn. In this short time the heat from the match changes some of the solid paraffin to a liquid and then to a gas. *It is the gas that burns.* As the gas burns, enough heat is given off to change more of the paraffin to liquid, and this in turn is changed to gas. This process continues until the candle is entirely gone.

Carbon Dioxide Is Produced by Burning. As the candle burns, certain changes are taking place. Paraffin is composed of two things: carbon and hydrogen. Some of the oxygen in the air combines with the carbon in the paraffin gas and forms carbon dioxide. Do you remember our discussion of carbon dioxide in Chapter III? It is the waste gas that we expel from our lungs in breathing. We can now show that a burning candle expels carbon dioxide too.

Exercise. How to show that carbon dioxide is produced when a candle burns: In this experiment you will need a bottle of limewater and two clean wide-mouthed bottles. Hold the mouth of one of the bottles directly over the flame of a candle for about half a minute, as shown on the opposite page. Then pour about two teaspoonfuls of limewater into each bottle and shake the bottles. The limewater in the bottle that was held over the flame will appear milky. The limewater in the bottle that was not held over the flame will remain clear. Carbon dioxide from the flame caused the change in the appearance of the limewater.

Water Is Produced by Burning. Oxygen from the air combines also with the hydrogen from the candle gas, and the result of the combination is water vapor. This, too, may be proved by a simple demonstration.

Exercise. How to prove that oxygen from the air combines with hydrogen in a burning candle to produce water vapor: Hold the smooth surface of a cold laundry iron two or three inches above the flame of a candle. Does moisture form on the iron?

Thus we see that oxygen from the air and carbon and hydrogen from the candle all play their parts in the process of burning. Changes similar to those which we have studied in the burning of a candle take place in all burning—whether it is wood, coal, or fuel gas which is being burned. As long as the things necessary for burning are present, burning takes place. When one or more are removed, burning stops.

hese children are showing that carbon dioxide is produced by a burning candle

What Elements Are. In experimenting with the candle we dealt with some of the most simple materials in the world. Such simple materials as oxygen, carbon, and hydrogen are known as elements. Gold, silver, aluminum, copper, and iron are some of the other elements out of which the earth is made.

Elements are the building blocks of our world. All the material things in the world—air, water, rocks, and living creatures—are made up of elements in one combination or another. Though only 92 elements have been discovered, they combine in enough different ways to make the millions and millions of different things in the world.

How may we define an element? We may say that *an element is made of but one kind of material.* No matter what we do to an element, we cannot discover any material in it but itself. We can grind a chunk of iron as fine as talcum powder, but we find no material but iron. Because each element is made up of only a single material, the element is the simplest form a material thing can have.

What Compounds Are. In burning the candle we made the oxygen in the air combine with the carbon in the candle to produce carbon dioxide, and with the hydrogen to produce water. *In other words, we made elements combine in such a way as to produce new materials which are not elements.* These new materials—carbon dioxide and water—are not elements because each one of them is the result of the union of two different elements.

What, then, are carbon dioxide and water? Are they mixtures, as cake and air are mixtures? Is carbon dioxide a mixture of carbon and oxygen as cake is a mixture of flour, sugar, and the other things that went into it? Is water a cakelike mixture of hydrogen and oxygen?

The answer is No. The union of the elements in carbon dioxide and water is much closer than the union of the materials in a cake. Such very close unions are known as compounds rather than mixtures. *A compound differs from a mixture because the elements that combine to make a compound completely lose their individual qualities.* You will remember that the materials which combine to make a mixture *do not* completely lose their individual qualities.

Water beautifully illustrates the nature of a compound. In our experiment with the candle we produced water by burning the hydrogen of the candle with the help of the oxygen of the air. In other words, *by combining an element that will burn with an element that makes burning possible, we produced a compound that will not burn.* We produced a material with entirely different appearance and behavior from the materials of which it is made.

No matter how small a drop of water we might study under the microscope, we could not see the hydrogen and oxygen whose union created the water. If the hydrogen were bright blue and the oxygen bright red, we still could not tell them apart in a drop of water—not even with the help of the most powerful microscope in the world.

It is marvelous that hydrogen and oxygen can combine in so close a union and form a compound so different from themselves as water. It is even more marvelous that, close though the union is, scientists have found ways of breaking it. They have found ways of turning water back into hydrogen and oxygen.

Many other compounds, some of them containing as many as three or four elements, can be broken down into the elements of which they are made. Indeed, if this were not possible, it would be difficult to tell whether a material was a compound or an element. So close is the union of elements in a compound that just looking at a compound does not ordinarily show that it is made up of more than one material.

THE WATER IN THE AIR

From Fire to Water. We began our study of a burning candle to see what we could learn about oxygen. We ended this study by learning not only about oxygen but about carbon dioxide and water vapor as well. It so happens that these two compound gases are important members of the family of gases which make up the air.

The Wandering Gas. In Chapter IV we saw how water is continually evaporating into the air from the surface of oceans, rivers, and lakes, as well as from the soil and from the leaves of plants. It is also continually falling out of the air as rain or snow, and on cool clear nights it settles as dew or frost. The amount of water vapor in the air as a whole is also forever changing. Water vapor is the only important gas in the air that varies in amount from day to day. We called oxygen the lively gas. With equally good reason we may call water vapor the wandering gas.

Perspiration. The amount of water vapor in the air around us has much to do with how we feel. The surface of our bodies is always slightly moist with water that comes from some two million tiny sweat glands in the skin. We call this water perspiration. It is constantly forming on our skin and evaporating from it.

More water comes out through the sweat glands in hot weather than in cold weather. In the same way, we perspire more when we are playing hard than when we are resting quietly. On the average, about two quarts of water pass through our sweat glands every day.

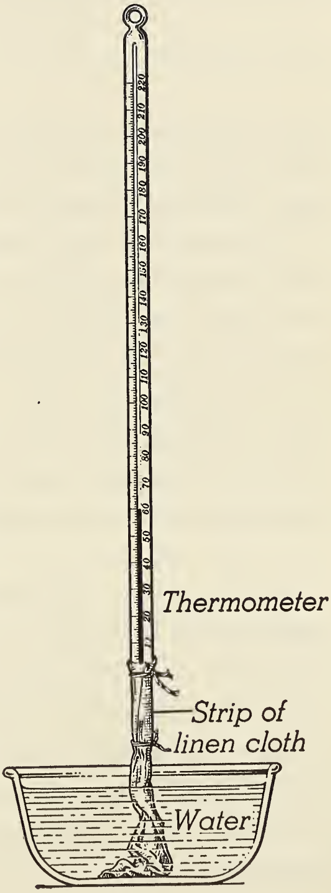
This water does not stay on the skin. It ordinarily keeps the skin moist but not wet, for it comes out slowly and evaporates as soon as it reaches the surface. There are some conditions, however, under which water evaporates slowly from the skin, and other conditions under which it evaporates rapidly. In either case we may feel more or less uncomfortable.

How the Temperature of Our Bodies Is Controlled. The evaporation of moisture from the skin helps to control the temperature of the body. *Evaporation is a cooling process*, as may be shown by a few simple experiments.

Exercises. How to prove that evaporation cools the skin:

Blow gently against the skin of your hand. Then moisten part of it and blow again. Does blowing on wet skin feel cooler than blowing on dry skin?

Get a thermometer, a strip of linen cloth, and a dish of water. Read the thermometer and record the temperature of the air. Now cover the bulb of the thermometer by wrapping one end of the piece of linen around it. Be sure that only one thickness of the cloth is used. Let the other end of the linen strip hang in the dish of water, as shown on the right. Watch the temperature of the thermometer as the cloth becomes soaked with water. What do you find? Now take the thermometer out of the water and fan the air around the bulb. Can you explain what happens?



You have no doubt noticed that there are some conditions under which perspiration seems to evaporate very slowly. You can probably remember hot sultry days when perspiration formed on your skin and collected in large drops. You felt very uncomfortable. You may have heard someone say that this was because "the humidity was high." Just what did this statement mean?

Humidity refers to the amount of water vapor in the air. When the humidity is high, there is a large amount of water vapor in

Though the temperature is the same, one man is enjoying himself and the other is not
What do you suppose might account for the difference

the air around you. When the humidity is low, there is less water vapor in the air around you. If the humidity is high, water will not evaporate rapidly from your skin.

There may be two summer days during which temperatures are practically the same. Yet you may suffer much more from the heat on one day than on the other. The reason is that the humidity is higher on the one day than on the other. You suffer more from the heat on the day when the humidity is high because high humidity interferes with the process of carrying heat away from your body by the evaporation of perspiration.

The Importance of Water Vapor. The influence of water vapor on our feelings of comfort and discomfort is only one illustration of the importance of this gas. In our unit on water we saw other illustrations of its importance. We shall see still others in all the remaining units of this book. Water vapor wanders everywhere, and wherever we look we shall find it. Wherever we find it we shall see it doing important things.

THE OTHER GASES OF THE AIR

Carbon Dioxide. In one very important sense carbon dioxide is just the opposite of oxygen. We have seen that carbon dioxide is produced by the processes of burning and breathing. It is one of the chief results of these processes just as oxygen is one of the chief causes. And *just as enough oxygen in the air is needed to make burning and breathing possible, enough carbon dioxide in the air will make burning and breathing impossible.* That is why carbon dioxide is used in fire extinguishers to fight fire. That is why you find it difficult to breathe when you pull the blankets over your head on a cold winter night.

Like water vapor, all the carbon dioxide that gets into the air does not stay there. Carbon dioxide is continually entering the air as a result of burning and breathing, but it is also continually leaving the air by uniting with the rain, the oceans, the rocks, and the soil. Unlike water vapor, *the amount of carbon dioxide that goes into the air is balanced by the amount that goes out.* The result is that the percentage of carbon dioxide in the air does not vary. About $\frac{3}{10,000}$ of the world of air is carbon dioxide.

This, you might think, is too small an amount to be of any importance. But carbon dioxide, like oxygen and water vapor, is a vigorous gas. Its importance lies not in its amount but in its activity. As with oxygen and water vapor, we shall continually meet carbon dioxide as we continue our explorations in the world around us.

The Lazy Gas. About 78 per cent of the air is made of nitrogen. Like the other gases of the air, it is colorless, odorless, and tasteless. Unlike oxygen, water vapor, and carbon dioxide, nitrogen is very lazy. It does not combine readily with other elements. Its importance in the world of air is not nearly so great as its quantity. But it dilutes the oxygen so that the earth does not go up in flame, and that is something. Outside the air—in soil and in the bodies of living creatures—the element nitrogen is very important, as we shall see in a later unit.

The Rare Gases. Let us now examine some of the rare gases which are known to exist in the world of air. Though all these gases together do not account for 1 per cent of the air, some of them are important because of their usefulness in industry.

Argon is one of these rare gases. It is sometimes used in electric-light bulbs. With a small amount of this gas in them, bulbs give off light which is very much like daylight. Have you ever seen a so-called daylight bulb?

Helium was known to be present in the sun years before it was discovered in the air. Still later it was found in the ground, in the natural gas (fuel gas) that comes from wells in western United States. Next to hydrogen, helium is the lightest material in the world. You have already learned that hydrogen will burn and that helium will not. Because of this, the importance of helium in the future development of the dirigible will doubtless be very great.

Neon is also a small but important part of the air. It is a colorless gas; but when an electric current is passed through a tube containing neon at low pressure, a red light is produced. The colored lights used in advertising signs, such as the one illustrated on the opposite page, and also the lights used to guide airplanes, are neon lights. These lights are useful at landing fields and as beacons along air routes because the neon light will penetrate through fog to a greater distance than any other kind of light.

Roberts

Neon gas is widely used in electric signs

So, finally, we come to the answer to the question "What is air?" We have learned that air is a mixture of gases, of which oxygen, water vapor, and carbon dioxide are the most important for what they do. In the mixture nitrogen is much the most abundant, and carbon dioxide, argon, neon, and helium the least abundant.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. A mixture is a combination of several materials in which the individual qualities of the materials are completely destroyed.

2. Because the gases of which air is made are all colorless, odorless, and tasteless, there is no way of telling one gas from another.

3. We can prove by experiment that all gases in the air take part in the process of burning.

4. It would be better for us if there were less oxygen in the air because then there would be fewer bad fires.

5. Paraffin is used in candles because it does not have to be turned into a gas before it will burn, and therefore burns more easily.

6. There is so large a percentage of nitrogen in the air because whenever anything burns this gas is produced.

7. Because there are very few elements in the world, elements are not important.

8. When elements combine to make a compound, they do not lose the qualities they had before they combined.

9. A "compound" is just another name for a mixture.

10. Water vapor is not an important part of the air because it is constantly leaving the air in the form of rain, snow, frost, and dew.

11. We feel hot in summer because perspiration evaporating from the surface of the skin raises its temperature.

12. "Humidity" is just another name for temperature.

13. Carbon dioxide, like water vapor, is not present in the air in any definite amount.

14. Nitrogen is much the most important gas in the air because it accounts for 78 per cent of all the air in the world.

15. Argon and helium are too rare to be of any use to us.

Questions for Discussion

1. We all know that some things burn well, other things poorly, and still others not at all. Discuss the probable reasons for this. Base your discussion on the experiments on page 185. When the lighted candle in one of these experiments was placed under a glass, only part of the oxygen in the glass was used up when the flame went out. When the phosphorus in the other experiment stopped burning, nearly all the oxygen under the jar was used up. Why?

2. Suppose the paraffin in a candle burned like a piece of wood, that is, without first becoming a liquid and then a gas. What difference would that make in the way the candle burned? Would paraffin still be a good material to use in making candles?

3. Discuss the possible reasons why a lighted candle goes out when you blow on it with your breath.

4. Look up the definition of "chemistry" in the dictionary. What parts of this chapter dealt with chemistry?

Things to Do

1. Read Faraday's *Chemical History of a Candle.*

2. You have already read something about the work of certain scientists. You may want to look up and read about the life and work of some others, such as Ramsay, Lavoisier, Cavendish, or Rutherford. These names are perhaps not as familiar to you as some others, but these men have all made important contributions to our knowledge of the air. See what you can find out about them and report your findings in class.

3. Test a number of different flames to see if carbon dioxide and water vapor are being produced. Follow the method described on page 190. You might try burning and testing a wood splinter, a match, a piece of paper, a piece of sulfur, a piece of rag, an alcohol flame, and a kerosene flame.

4. Plan some experiments to find out something about the cooling effect of evaporation. Try several kinds of liquids, such as ether, alcohol, water, and carbon tetrachloride. One way would be to place a small amount of cotton around the bulb of a thermometer and wet it with a few drops of the liquid to be tested. Keep a record of the temperatures produced at the end of one minute.

CHAPTER NINE

What Are the Differences Between Good and Bad Air?

THE DUST IN THE AIR

Where We Find Dust. Have you ever heard anyone say, "No matter how often this house is cleaned, it is always dusty again the next minute"? Have you ever emptied the bag of a vacuum cleaner? Sometime when the rays of the sun are streaming through a window, take a broom and sweep the floor. Do you see anything in the rays of light? Is any dust floating in the air?

Even when you do not stir it from the floor with a broom, there is always dust in the air. An easy experiment will prove it.

Exercise. How to show that dust is present in the air: Get two or three small pieces of glass. Clean them thoroughly and then smear the surface of each with vaseline. Put each in a different place. One might be put outside the window of your classroom, one in your cellar at home, and another in your bedroom. After two or three days examine them carefully. What do you find?

Many common experiences show that wherever there is air there is dust. You have no doubt noticed dust on furniture, automobiles, or clothing. You have probably found an unusually large amount of it on your face when you washed after a trip in an automobile or train. Your eyes, nose, and mouth may have been filled with dust after walking in a strong wind.

Examination of the air outside the fifty-eighth floor of a New York office building once showed thirteen particles of dust per cubic inch of air. At the street level the air carried sixty-eight dust particles per cubic inch.

What Dust Is. All these experiences prove that the air is loaded with dust. What is this dust and where does it come from?

Exercise. How to make dust: Rub a piece of blotting paper with the eraser of your pencil. The paper is broken into small bits that may be carried by the wind. The bits of paper are one kind of dust.

Many other kinds of dust are continually being made in much the same way. The wheels of automobiles and wagons crush stones and rubbish to powder. Rocks fall as a foundation is dug, and clouds of dust rise into the air. Ash barrels are emptied on a windy day. Loads of dirt are dumped into an empty lot. Fields are plowed. All these things and many others are makers of dust.

The eruption of a volcano may throw fine rock dust into the air which the wind may carry to every corner of the world. Meteors burn and change to dust as they dive from space into the air surrounding the earth. The larger particles of dust settle when the air is still, but they are lifted up again when the next breeze stirs. The finer particles may float in the air for days or even months before they settle on the ground.

In cities where soft coal is burned, an enormous amount of soot escapes from the chimneys and is scattered about the city as dust. The photograph on page 204 gives you an idea of what industrial progress may do to the air we breathe. A report from one large industrial city shows that

Galloway

If you want to see why large cities are dirty,

just count the chimneys and smokestacks in this pictu

1031 tons of soot fall on each square mile of that city in twelve months. It is easy to understand why such a rain of soot quickly soils clothing and collects as black dirt on the skin and in the nose.

Dust Storms. Dust of a different sort has been much in the air—and in the news—of recent years. The terrible dust storms of the Western Plains, which turn day into night and bury whole counties inches deep under wind-blown earth, have taken their place among the major disasters. On the opposite page you can see what a dust storm can do to a farm.

The unhappiest fact about dust storms is that they are for the most part unnecessary. Nature covered the dry Western Plains with grass, which normally anchors the soil to the surface of the earth. Only where men have plowed up this grass, or allowed cattle and sheep to destroy it by too close grazing, has the wind been able to sweep the soil into the air.

The solution of the problem of dust storms is to remove the cause. Regions which nature did not mean to be farm lands or pastures must be allowed to return to grasslands. *To restore and preserve these lands is one of the most pressing problems in the whole field of conservation.* We shall learn more about this problem and its solution later.

Nonliving Dust. Is dusty air harmful to us? To some extent, yes. You can easily imagine what dust could do to our lungs if much of it gathered there. Fortunately the passages leading through the nose to the lungs are so built that most of the dust is removed from the air before it reaches the lungs. Much of the dust is caught by tiny hairs on the moist surface of the nose and is removed when we

This farm is only one of many that have recently been smothered by dust

U. S. D. A. Soil Conservation Service

use our handkerchief. Do you see why it is important that we should breathe through our noses and not our mouths?

There are certain trades, such as those of stonecutter, cement worker, and tool-grinder, in which the workers are definitely injured by the dust in the air. Stonecutters and tool-grinders are very likely to have lung trouble, caused by inhaling dust. People living in the smoky air of industrial cities may also be injured if they breathe for a long period of years the tiny black particles of carbon that come out of the chimneys.

The dust we have been discussing is called nonliving dust because it is made up of little particles of soil, cinders, smoke, and other lifeless things. It is unpleasant and in some cases harmful. There is also another type of dust, which is known as "living dust." This form of dust consists mostly of very small plants. Some kinds are harmless, some are useful, but some are very dangerous.

LIVING DUST

Pollen. One kind of living dust in the air is the pollen of flowers. You may remember having seen this yellow or brown powder as it fell from some flower in full bloom. The pollen must be blown by the wind or carried by insects from one flower to another before the seeds can form. Many communities destroy various types of pollen-bearing flowers or weeds because the pollen from some of them causes hay fever in certain people by irritating the nose and throat. A common plant responsible in some cases for this unhappy condition is

The ragweed plant is an enemy of nose and throat

U. S. Public Health Service

Life Magazine

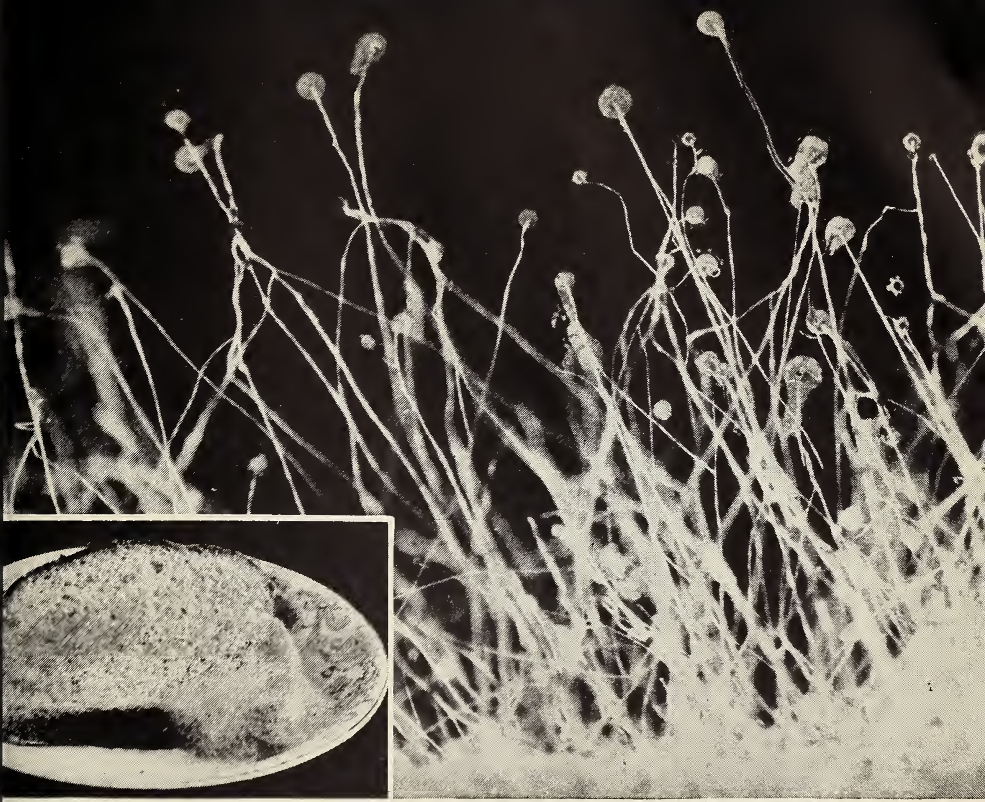
This girl is sneezing, not laughing. Hay fever is no fun the ragweed, shown on page 206. Its pollen is carried by the wind.

Molds. Another kind of living dust comes from tiny plants known as molds. Molds produce tiny particles called *spores*, and the spores float around in the air. When they fall on "fertile ground," such as bread, moist leather, or damp cloth, they grow and produce new mold plants. You can easily demonstrate this fact by an experiment.

Exercise. How to show that molds are present on common foods: Moisten a piece of bread and place it in a covered dish so that water will not escape by evaporation. Place the dish in a warm dark place. Examine the bread after one day, after three days, and after a week. Describe what you see.

The growth that developed on the bread in the above experiment is mold. The spores of the mold had settled on the bread from the air before you made the experiment. All you did was hatch them. People say that such bread is "moldy" or "mildewed." Moldy bread is not pleasant to eat, but it is not especially harmful. The molds that spoil food are not the only kinds. Certain molds and tiny plants resembling molds are useful in developing the flavor of cheese. Others cause disease among trees and grains. Still others are responsible for certain skin diseases, such as athlete's foot, in man.

Yeast. Yeast is a third kind of living dust. You buy yeast in the grocery store in small cakes. These cakes contain millions of tiny living yeast plants. Some kinds of yeast plants float in the air. If, when the weather is warm, a single yeast plant happens to fall into sweet fruit juices, it will grow and form new plants very rapidly. Very soon



Hugh Spencer

Moldy bread is not inviting

there will be a million plants where a few hours before there was only one.

These little plants frequently spoil canned fruits and fruit juices by changing some of their sugar into carbon dioxide and alcohol. When fruits or vegetables are preserved at home, we must be very careful to seal the jars tightly so that as much air as possible is kept out. Cans for fruits, vegetables, and juices of all kinds should be as nearly air-tight as they can be made. Do you see why this is necessary?

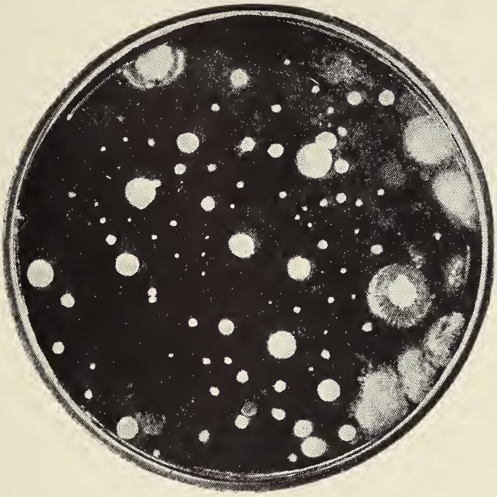
Bacteria. A fourth kind of living dust is bacteria. These tiny plants, which we have already studied in connection with water, are also present in soil and air. As we learned in Chapter V, some bacteria are very helpful, but others cause serious trouble. Certain bacteria add nitrogen to the soil and thus help to nourish our food plants. Certain others change solid sewage to liquid and thus help to dispose of it. Still others help us to digest our food.

Unfortunately, harmful bacteria are present in many places. A single diphtheria bacterium taken from the air by breathing may cause diphtheria. Tuberculosis, lockjaw, typhoid fever, dysentery, spinal meningitis, scarlet fever, and other diseases are caused by bacteria, each kind different from the others. Turn back to page 108 and study again the appearance of bacteria.

There are many bacteria, both good and bad, in the air. An examination of air at the street level of one large city showed 1330 bacteria in each cubic foot of air. At the level of the tenth story of a building there were 330 in a cubic foot. In a cubic foot of "pure" country air as many as 50 bacteria have been found. In crowded shops the number may be as large as 1000.

How to Grow Bacteria. Scientists can show by a simple demonstration that bacteria are always present in the air. You can make this demonstration yourself.

Exercise. How to grow bacteria: Boil a cupful of beef broth for two or three minutes to kill all the bacteria it may contain. Then add a teaspoonful of gelatin so that when the mixture cools it will form a jellylike mass. Pour half the mixture into one flat dish and the other half into another flat dish. Cover the dishes and let them cool. Next lift the cover of one dish and shake a handkerchief over it. Replace the cover. Keep the second dish tightly covered. Place both dishes in a warm place for a few days. Observe the dishes from time to time. After a few days the mixture in the dish over which you shook the handkerchief will probably have little spots on its surface, as shown on the opposite page. The mixture in the other dish should remain clean. As time passes, the spots grow larger and larger. Each spot is composed of many thousands of bacteria.



Each spot on this jellied beef broth is a cluster of many thousands of bacteria

Where did these bacteria come from? Why did they grow in one dish and not in the other? Is it not clear that when you shook the handkerchief over the one dish of jellied broth, a few bacteria must have settled in it? Single bacteria are so tiny that you cannot see them except with a very good microscope. But with plenty of food and warmth they increase very rapidly. In a few hours a single bacterium increases to hundreds of bacteria and in a few days to thousands of millions. These feed upon such food as you provided in the experiment, and in the process of growth form a large enough spot to be seen by the naked eye. Each of the spots probably began as a single bacterium. The number of single bacteria that settled on the broth while the cover was off the dish can be determined by counting the number of spots.

On Avoiding Harmful Bacteria. Fortunately most of the bacteria that settle on us and on our clothing from the air are harmless. But dangerous bacteria which cause a variety of diseases may enter the air from people who are ill. Such people may be breeding grounds for harmful bacteria. During normal, quiet breathing practically no bacteria get into the air from the lungs, even from people who have a bacteria-produced disease. In coughing, sneezing, or even in talking, on the other hand, tiny droplets of saliva are sprayed into the air. These are very likely to carry bacteria.

If the saliva comes from a person suffering with a cold, diphtheria, or tuberculosis, it is dangerous. The droplets float in the air and may be taken into the body of another person when he breathes. Most people cover their noses and mouths when they sneeze, but there are, unfortunately, some who do not. One should stay away from the careless and thoughtless person who does not cover his mouth with his handkerchief when he coughs and his nose when he sneezes.

THE NEED FOR CLEANLINESS

Clean and Unclean Habits. From the above discussion you can see the necessity for cleanliness. No person who is careful about cleanliness would think of using a handkerchief which someone else has used. The danger of doing so is too great, especially if the person who owns the handkerchief is suffering from some illness. Similarly no person who is careful about cleanliness would think of using someone else's toothbrush.

Careless people use towels, washcloths, combs, hairbrushes, and other toilet articles which other members of the family or even strangers have used. These are unclean

Galloway

There are clean and unclean ways of cleaning the hands

practices and may result in illness. Many common ailments, such as skin and scalp diseases, are spread in this way.

Not so many years ago, roller towels in washrooms were used by everyone. Everybody drank water from the same cup or glass. Today most states and cities have laws against the common use of such articles. We have paper towels and sanitary bubbling drinking fountains. As a result of our increased knowledge of dangerous bacteria, greater precautions are rather generally being taken. The result is that all of us are healthier.

Care of the Hands. Personal cleanliness today is largely a matter of good taste and good manners. But it is also a matter of good health. An increasing number of people realize the dangers of getting too friendly with unfriendly bacteria. Some boys and girls look at their hands before eating and then decide that they are clean enough without washing. Yet they would not consider a doctor very careful who did not wash his hands before an operation.

Each of us handles many objects which may be covered with bacteria, some harmless but others dangerous. We shake hands with other people. We hang on straps in crowded trains and trolley cars. We do many things every day which cover our hands with bacteria. Do you see why we should clean our hands thoroughly with soap and warm water before each meal? Fingernails especially should be kept as clean as possible, because bacteria flourish beneath these sheltering roofs.

Care of the Rest of the Body. The skin of the whole body should be kept clean. Cold water will not properly remove the dirt which collects in the pores of the skin. Warm water and soap are most effective for removing dirt; so warm baths should be taken often. Soap should be used freely. Cosmetics should be used with caution because some are poisonous and cause ugly skin eruptions which are breeding places for bacteria.

Special attention should be given to the cleanliness of the nose, throat, and teeth. The nose and throat, in particular, are favorite gathering places for bacteria. By careful attention to the cleanliness of these two organs we can do much to prevent the common cold, which in some cases paves the way for more serious illness.

Why Cleanliness Pays. There are some people, to be sure, who carry cleanliness to a silly extreme. They wash after every handshake. They are forever using mouth washes and gargles. Such extreme precautions are not necessary. Reasonable habits of cleanliness will go far in preventing the spread of bacterial diseases.

The person who first said that cleanliness is next to godliness expressed a very important truth. When a person is in good health, his body is usually able to resist the attacks of disease—but not always. Even when we are well it does not pay to run unnecessary risk. It is much safer to keep our bodies clean. It is also much more pleasant—for ourselves as well as for others.

DANGEROUS GASES IN THE AIR

Carbon Monoxide. Are there any harmful gases in the air? Is carbon dioxide dangerous? Are water vapor, oxygen, and nitrogen dangerous? The answer is that not one of these ordinary gases of the air is harmful to us so long as it is present in a normal amount. There is a gas, however, which gets into the air and which is extremely dangerous even in small amounts. That gas is carbon monoxide. Do not confuse carbon monoxide with carbon dioxide. Though sister gases, they are very different in behavior.

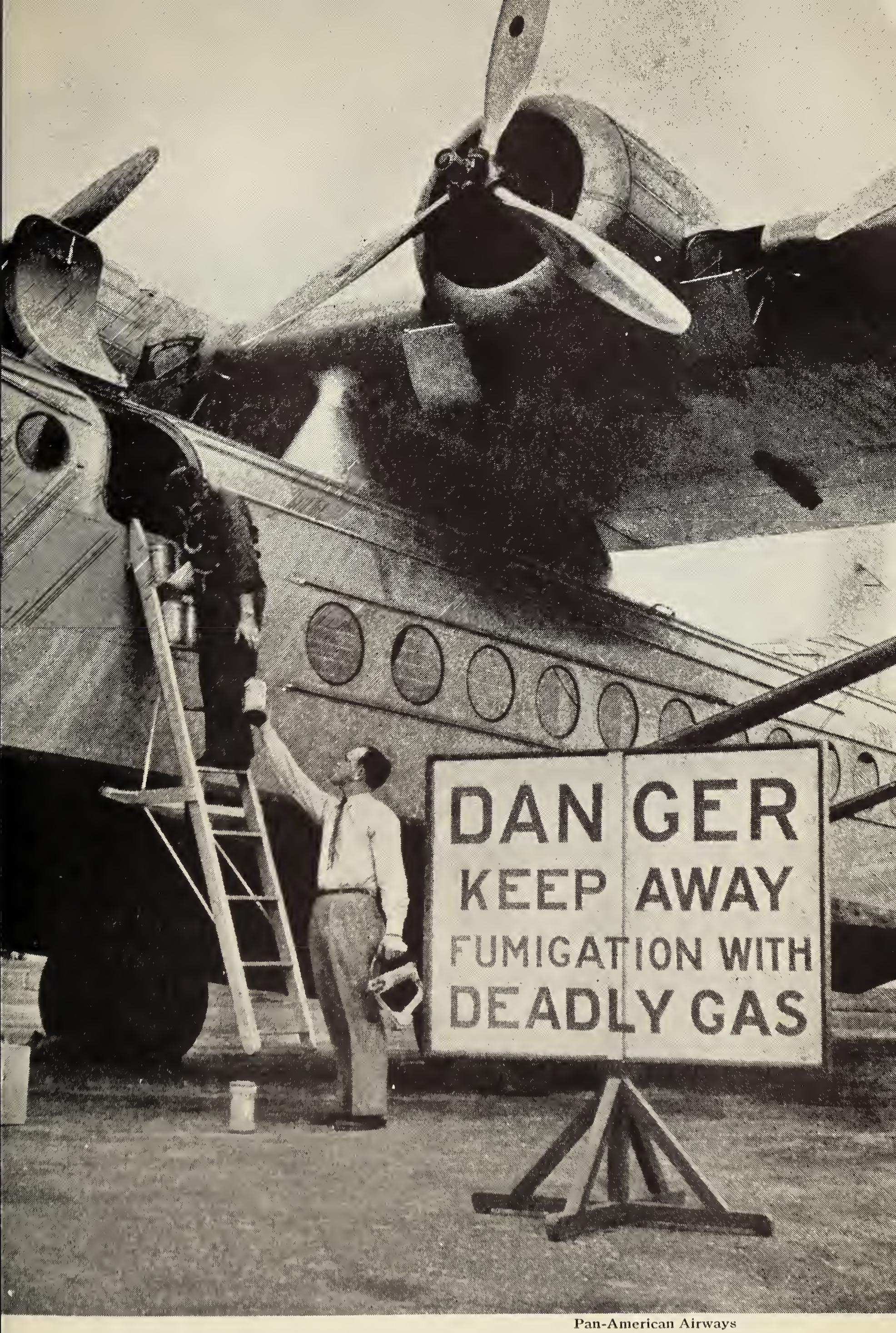
ping oxygen into the lungs will sometimes revive people who have been overcome by poisonous gases

N. Y. Fire College

The Good Sister and the Bad. Where does carbon monoxide come from? You have already learned that its sister gas, carbon dioxide, is one of the products of burning. This is also true of carbon monoxide. When the carbon in such things as gasoline and coal burns in air or oxygen, the carbon combines with the oxygen. If there is enough oxygen for the burning process, the harmless carbon dioxide is produced. If there is not enough oxygen for complete burning, the dangerous carbon monoxide is produced.

Under ordinary conditions both carbon dioxide and carbon monoxide are formed when gasoline is burned in the cylinders of an automobile. If the carburetor is properly adjusted, however, only a very small amount of carbon monoxide is formed. Outdoors the carbon monoxide from the exhaust mixes with the air. The proportion of the dangerous gas is ordinarily so small that it produces no noticeably harmful effects, even on crowded highways. In a closed garage, however, the poisonous carbon monoxide may collect in a large enough quantity to be extremely dangerous. You may frequently read in the newspapers of people who have been killed by carbon monoxide while working in small closed garages or on automobiles with their engines running.

Carbon monoxide may also be given off by coal which is burning in a stove or a furnace. Some of this poisonous gas may enter the room if the drafts of a stove or furnace are not properly adjusted or if a flue or a chimney leaks. Gas and kerosene heaters which lack chimneys or flues may also become dangerous if the fuels used in them are not completely burned. Rooms in which such heaters are used should be frequently aired.



Pan-American Airways

dly gases have their uses. Any harmful germs or insects that may have stolen a
on this airplane from South America will no longer be harmful when these men
have finished their work

THE CONSERVATION OF AIR

Air as a Natural Resource. We do not ordinarily think of air as a valuable treasure that can be wasted and abused. Air is everywhere and free to all; so why do we need to conserve it? The answer is that though air is plentiful and cheap, air in the places where most people live is not always good. A supply of good air, like a supply of good water, can only be had through the practice of conservation.

What Makes Air Good. Now that we have learned that dust, bacteria, and carbon monoxide make the air bad, let us see what makes it good. Human beings can adjust themselves to many different conditions, but they seem to be most energetic, comfortable, and healthy when the air has the following qualities:

Pressure which is generally about 15 pounds per square inch.
Content of about 21 per cent oxygen and a small amount of carbon dioxide mixed with nitrogen and other harmless gases.
Temperature which changes considerably during each day as well as from day to day but which ranges, for the most part, between 50° F. and 70° F.
Humidity which is generally neither very high nor very low.
Slight movement most of the time.

Each of the above conditions helps determine whether the air we breathe is good or bad. When we are outdoors there is little we can do about any of these conditions. On the whole, they are part of the world around us which we cannot change.

In this modern age, however, we live chiefly indoors. Our problem is to make the indoor air as good as possible. Fortunately we can do this very successfully through proper ventilation. But exactly what is proper ventilation?

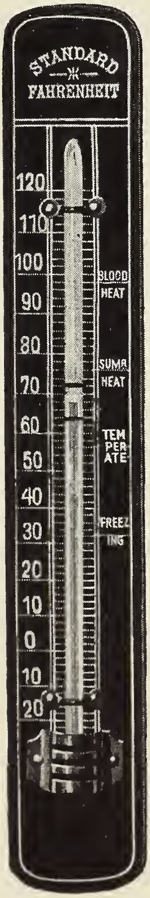
What Ventilation Means. The word "ventilation" means "to let in the wind." The best ventilation, however, will do more than this. It will produce *all* the air conditions listed above as most favorable for health and comfort. Of course the air in any given room at any given time may not be absolutely perfect in every respect. Even so it will not necessarily be harmful, especially if a bad condition does not last too long. Modern ventilation, however, attempts to keep all conditions of the air in buildings always as near as possible to the ideal—and it succeeds remarkably well.

The Proper Pressure. Under ordinary conditions no attention need be given to air pressure in ventilating a room. Only when special problems arise in relation to the air supply (as in deep-sea diving or in flying to high altitudes) does the artificial regulation of air pressure become necessary.

The Proper Amount of Oxygen and Carbon Dioxide. Air containing 21 per cent of oxygen and but a trace (3 parts in 10,000) of carbon dioxide is without question the best kind of air to breathe. It has nevertheless been demonstrated by experiments that people may live fairly comfortably in air which contains less oxygen and more carbon dioxide. In these experiments people have been kept in tightly closed rooms, breathing air especially prepared so as to contain as little as 18 per cent of oxygen and as high as 2 per cent of carbon dioxide. These people were quite comfortable. In fact, they were unaware that the air they were breathing was in any way different from the air outdoors.

Such extreme changes in the oxygen and the carbon dioxide content of the air may be made to occur in the laboratory, but they do not occur in nature. Under usual living conditions there is almost no chance that the percentage of oxygen and carbon dioxide in the air of a room will be changed enough to produce definitely harmful effects. Besides, even in what may seem to be a tightly closed room, air is constantly passing in and out through cracks around doors and windows. When the air outdoors is at 0° F. and the air indoors at 70° F., there is nearly a complete change of air in one hour in an ordinary house. The conclusion to be drawn from all this is that *under ordinary circumstances we need not be concerned about the oxygen and the carbon dioxide content of the air.*

The Proper Temperature. From the point of view of health, comfort, and energy *temperature is much the most important condition of the air.* The air in a room in which people are sitting should never go below 64° F. nor above 72° F. Notice how the thermometer on the left is marked to indicate these limits. In factories where men are working at hard physical labor the temperature should be considerably lower than in a living-room. The temperature in the schoolroom should change



The temperature of a room should be kept within the limits marked on this thermometer a little from time to time. But for the very greatest health, comfort, and energy of the pupils it should never go much higher than 70° F. or much lower than 68° F.

Exercise. Keep a daily record of the temperature in your classroom or in your home, and see if it meets the requirements of health, comfort, and energy.

The Proper Humidity. There should always be considerable water vapor in the air we breathe. It is not healthful to live for long periods in very dry air. If it were possible to get perfectly dry air, the humidity would be referred to as 0. In air that holds as much water vapor as is possible the humidity is referred to as 100. No fixed percentage of water vapor is necessary for health and comfort. People may be quite comfortable within rather wide limits. In the best outdoor climates, however, humidity varies from 40 on hot dry days to 100 when it rains. In most climates during clear weather humidity generally varies from 40 to 70. *Air such as this—which contains on the average a little more than half the water vapor it is able to hold—seems most satisfactory for health and work.*

The chief humidity problem in cold and temperate climates is to keep the moisture content of our houses high enough in winter. Artificial heating drives water vapor out of the air. Many houses in winter are as dry as deserts—even when it is snowing or raining outdoors. This dryness weakens the tender linings of nose and throat and makes us an easier victim to harmful bacteria.

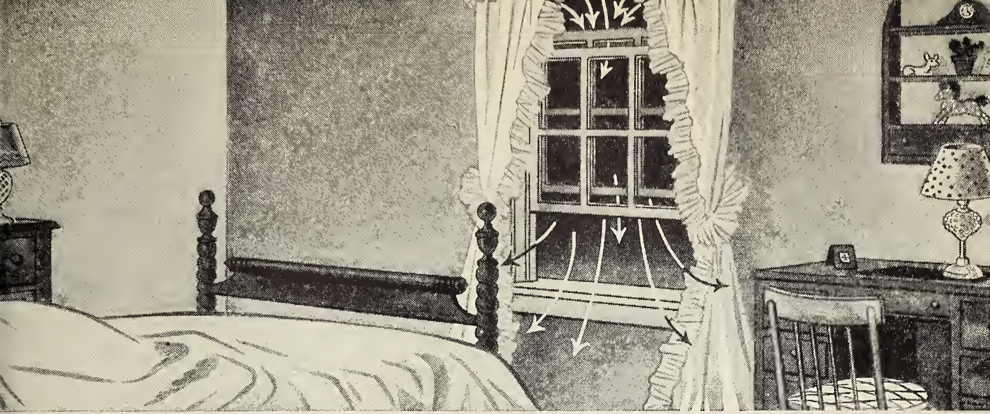
In very modern heating systems water vapor is distributed to the rooms of a house with the heat. Most houses, however, do not yet have this very modern equipment. The old-fashioned habit of keeping a pot of water on the kitchen range is still a good one. If we keep flat pans of water in every room during winter, we can offset, at least a little, the harmful effects of too low humidity. Opening the windows as often as possible, and not allowing the temperature to climb too high, will also raise the humidity.

Exercise. Place a pan of water on a heated radiator or near a hot-air register. How long does it take for the water to evaporate? Does the air seem thirsty for water?

Conditions may develop in which the humidity in a room becomes very high. This condition causes greater discomfort, though probably less harm, than low humidity. It may be remedied by allowing a draft of fresh air to enter and replace the stale moist air. Unpleasantly high humidity

In summer unpleasantly high humidity is highest and most unpleasant in overcrowded rooms. How could the humidity in this room be lowere

Wide World



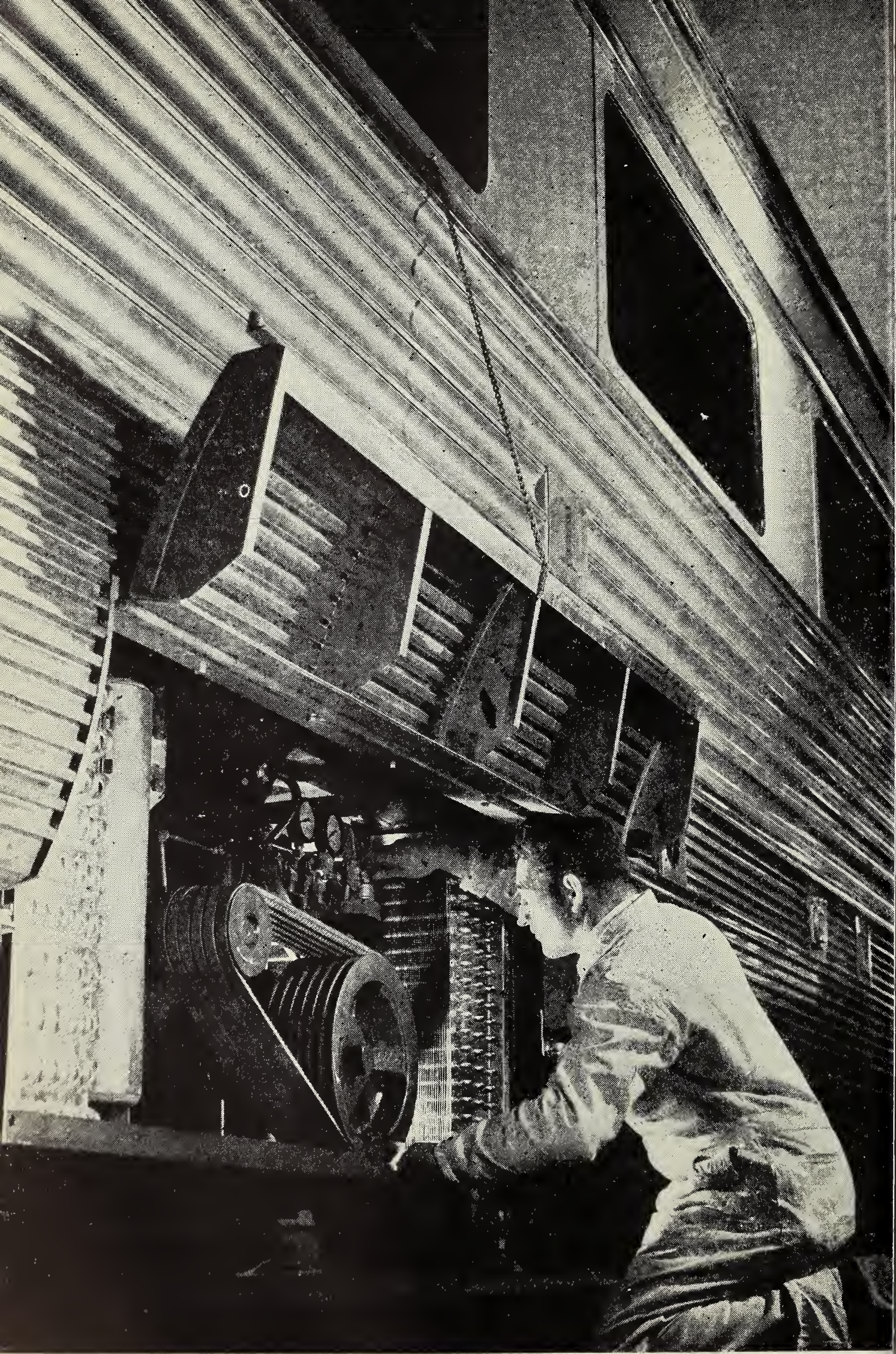
ndows in bedrooms should be opened at both top and bottom. This allows warm to leave at the top and cold air to enter at the bottom, thus setting up a gentle but steady circulation of air in the room

generally develops in summer and in overcrowded rooms like the one on the opposite page.

The Proper Movement. The last condition which proper ventilation must secure is movement of air. The movement should be only barely noticeable. A window which is slightly opened is sufficient under ordinary circumstances. Sometimes an electric fan may be used to keep the air in motion.

Ventilation in the Home. All these conditions may be satisfactorily controlled in the home by window ventilation. The picture above illustrates how currents of air pass in and out of open windows. Large rooms, such as theater auditoriums or lecture halls, need special machinery for ventilation. The new streamlined trains, as shown on page 224, all have modern ventilating systems.

From what you have now learned you can conclude that the most healthful and refreshing air is that which resembles outdoor air on a pleasant day. We are likely to call air "fresh" when it is pleasant and stimulating; that is, when there is moderate temperature, moderate humidity, and a slight breeze. These are the conditions under which we should strive to live.



Edward G. Budd Manufacturing Company

With the help of this air-conditioning unit the passengers on a modern train are provided with ideal weather regardless of conditions outs

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The dust in the air is made up wholly of such nonliving material as fine sand, soot, and cinders.

2. Because the wind blows more freely in the country than in the city, there is actually more dust in country air than in city air.

3. It is unnecessary to cover the mouth when coughing because saliva never contains any harmful bacteria.

4. It is perfectly safe to use the towel of a person ill with a cold because harmful bacteria die as soon as they leave the human body.

5. A well person need take no precautions against harmful bacteria because he is naturally protected against them.

6. Poisonous gases never get into the air in sufficient quantities to be harmful to our health.

7. Carbon monoxide and carbon dioxide are sister gases which are practically the same in origin and behavior.

8. Proper ventilation of houses is necessary for the ill but not for the well.

9. The most important problem of proper ventilation is how to keep the right proportion of oxygen in the air of our homes.

10. In winter the temperature of the schoolroom should be kept as close as possible to 75° F.

11. One of the greatest dangers of winter is that our houses may get too cold and damp.

12. Because any movement of air in a room is likely to produce a harmful draft, we should try to keep the air in our houses as still as possible.

Questions for Discussion

1. We hear a great deal about modern "air-conditioning" in theaters, restaurants, and trains. What do you think air-conditioning does to the air?

2. Do you approve of "antismoke" laws which have been passed in certain communities? How might such laws help make a community a healthier place in which to live?

3. Certain industries are dangerous because of the fine dust which they produce. Do you think it wise and just to have laws which would force an industry of this kind to guard the health of its employees? Why?

Things to Do

1. If you have a board of health or a health department in your community, look up and report on any laws it may have drawn up to prevent the spread of bacterial diseases.

2. Write to some insurance company for information on what such companies call "hazardous occupations." How many of these are called hazardous, or dangerous, because of dangerous air conditions? What occupations are they, and what air conditions make them dangerous?

3. Think over what you have learned about the dangers of bacterial disease, cleanliness, and satisfactory air conditions. Make a "Health Creed" of rules which you consider necessary to health.

4. Have a class representative write to some company that sells ventilating systems and get information about how they work. You will find addresses in the advertisements of nearly every popular magazine.

5. Have you ever heard of the Black Hole of Calcutta? Look it up and see what relation it has to this chapter. What air conditions caused it to be called the Black Hole?

UNIT FOUR

THE WORLD OF ROCK

EXPLORING THE WORLD OF ROCK

Some of us live in the mountains and some of us live on the plains.

Some of us live near rivers and some of us live near the sea.

But wherever we live we live in a world of rock.

◆

Rock and soil are our neighbors.

They are quiet neighbors, and we are likely to pass them by without realizing how interesting they are.

They are helpful neighbors, but we are likely to use them without even knowing that we have done so.

◆

Unit Four of this book is going to call on these neighbors.

It is going to see just what they are and what they do.

If you come along, you will get acquainted with some of the most interesting and useful things in the world.

CHAPTER TEN

What Is Rock?

ROCKS ARE LIKE PEOPLE

Rocks and Men. If you were asked the question "What is man?" could you answer it? The chances are that you would have difficulty, because "man" is so many different things. "Man" is white men, red men, yellow men, brown men, and black men. "Man" is also tall men and short men, fat men and lean men, jolly men and not-so-jolly men. "Man" is also the men of today, the men of Shakespeare's day, and the men who built the pyramids. "Man" is also many other things. What, then, *is* man? About all we can say is that man is a great many different kinds of men.

Now that we are about to explore the world of rock, we shall have the same sort of difficulty with the question "What is rock?" We did not have this difficulty with water and air. We found that water is always fairly simple, whether in the form of a liquid, a solid, or a gas. We found that though air is more complex than water, it is made up of relatively few different things, most of which we can name and study. But the world of rock, like the world of men, is composed of so many different things that we hardly know where to begin our explorations.

Where to Begin. Henry David Thoreau was a great American writer who believed in making everything as simple as possible. Once when at table and asked what food he liked best, he replied, "The nearest." In looking for the best place to begin our studies on the world of rock, we might well begin in our own back yard. *The best rocks to study first are the nearest ones.*

No matter where you live you can find a variety of rocks. If you live near the sea or a lake, you can find a variety of pebbles which the waves have piled up on the shore. If you live near a river or a brook, you can find a variety of stones along the banks. There are loose rocks of many kinds along automobile highways everywhere and in quarries, gravel pits, and fields.

Exercise. How to make a collection of rocks: Go to several different places in your neighborhood and collect as many different kinds of rocks as you can find. Take a hammer along so that you can break off small pieces of rock which will not be too heavy to carry, and a bag or knapsack in which to carry them. Try not to collect two specimens that look exactly alike on their freshly broken surfaces. See which member of the class can find the greatest variety of specimens.

No two collections of rocks in any given locality will be exactly the same. Certain kinds of rocks, however, will probably be present in all collections. These are the common rocks of your neighborhood and you will quickly learn to recognize them. They may be called the "natives."

Certain other kinds of rocks may be found in only one or two out of a dozen collections. We may call these rocks the "visitors," because the chances are that they were brought into your neighborhood from somewhere else. They may have been brought in by the ocean or a stream or by the men who built the roads. Much the best place to discover a great many different kinds of rocks is along a river or brook. Running water gathers up rocks as it flows and then later drops them.

To see what a rock really looks like, you must have a freshly broken surface

What Classification Is. After you have made a rock collection, you should do what a teacher does with a new class of pupils. No two of the pupils look exactly alike. No two dress exactly alike. No two have exactly the same name. The teacher's first task is to learn how each pupil is different from all the others in the class.

A teacher is able to divide a class at once into certain groups of pupils—a group of boys and a group of girls, for example. Though no two pupils are exactly alike in every respect, all the boys are alike in being boys, and all the girls are alike in being girls. In the same way the teacher can soon divide the class into other kinds of groups. Some pupils may be alike in enjoying arithmetic more than geography. Other pupils may be alike in enjoying geography more than arithmetic. In one way or another the class may be divided into groups of different pupils who are yet alike with respect to one particular quality.

To arrange different people or things according to their likenesses is known as classification.

How to Classify a Rock Collection. Let us see if you can do with your collection of rocks what a teacher does with a collection of pupils. When you made your collection you sharpened your eyes for the *differences* between one specimen and another. You should now sharpen your eyes for the possible *similarities* among your different specimens.

On careful examination you may find that some of your specimens look like pieces of coarse gravel, all cemented firmly together (see picture on page 238). We can speak of such rocks as *coarse-grained.* Some of your specimens may be made of much smaller grains, but grains which are visible to the naked eye or with the help of a magnifying glass (see picture on page 242). We may speak of such rocks as *fine-grained.* Some may be made up of both coarse and fine grains, as shown on page 252. Such rocks may be called *irregularly-grained.* Finally some may not show any grains at all, like the rock shown on page 245. We may call such specimens *glassy.*

To separate rocks into groups of different grains is to classify them by texture. The word "texture" means "weave." The texture of a piece of cloth, for example, refers to the kinds of threads it contains and to the way they are woven together. In the same way the texture of a rock refers to the kinds of grains it contains and to the way they are put together.

Exercise. How to classify a rock collection by texture:

Divide your specimens of rocks into four groups: coarse-grained, fine-grained, irregularly-grained, and glassy. If you do not have examples of every group, make as many groups as you can.

After you have classified your collection by texture, look again at the grains in each specimen. Use a magnifying glass if possible. Are all the grains in a given specimen alike? If not, are they different in shape? in smoothness? in shine? in color? in any other ways?

Exercise. How to make a table of descriptions of several rock specimens: Classify the specimens according to their texture and the quality of the grains of which they are composed. The following is a sample of the kind of observations your table should contain:

Specimen	Texture	Grains	Description of Grains
A	*Coarse-grained*	*3 kinds*	*Some grains irregular, transparent, and glassy* *Some grains with square sides, pink, smooth* *Some grains oblong, shiny, black*
B	*Irregularly-grained*	*2 kinds*	*Some grains the size and appearance of sand* *Some grains like pebbles the size of grapes, white and brown*
C	*Fine-grained*	*1 kind*	*All grains gray and fine as powder*
D	*Glassy*	*No grains*	*No grains visible even under magnifying glass. Specimen looks like piece of smoked glass*

Rock Relationships. By describing your specimens in the way shown in the table you will "get the feel" of them. You will become familiar with the characteristics which show how different kinds of rocks are related. Rocks are like people. Some are as closely related as sisters and brothers. Some are like first cousins. Some are like distant cousins. Some are so unlike as to appear wholly unrelated.

There are three great groups of rocks just as there are three great races of people. The rocks in each of these groups were formed in an entirely different way from the rocks of the other two groups. Just as you can see the differences between a black man, a yellow man, and a white man, you can learn to see the differences between the members of the three great "races" of rocks. And just as you can become acquainted with individual members of a race of men, you can also become acquainted with individual members of the "races" of rocks.

The remainder of this chapter will introduce you to some of the most interesting members of the three great "races" of rocks.

THE IGNEOUS ROCKS

Child of the Sun. All scientists are agreed that the earth is a child of the sun. The sun is a ball of white-hot gases, many times larger than the earth. Great tongues of glowing gas are forever shooting out from the surface of the sun like flames from a mighty bonfire. Ordinarily these fiery tongues are drawn back into the body of the sun. Only one of them is ever known to have escaped.

Many scientists believe that ages ago—nobody knows exactly when—a tremendous jet of gas tore loose from the surface of the sun. Out in the bitter cold of space it cooled and broke up into several balls which we call the planets.

Our earth is one of these planets. The gases which made up the outer portions of the young earth cooled first to the liquid and then to the solid form. The earth is now very old, but volcanoes prove that it is still very hot inside.

The rocks that came into existence when the earth began to turn solid are known as the "igneous" rocks. "Igneous" means "fiery," and refers to the origin of these oldest rocks in very hot gases and liquids. Rocks that have flowed or been blown out of volcanoes at later dates are also called igneous, because they too were born of terrific heat. The igneous rocks are one of the three great "races" of rocks.

How to Recognize the Igneous Rocks. All the ninety-two elements known on earth are found in the igneous rocks. As these rocks took solid form the elements combined into a great many different compounds which are known as *minerals.* The minerals were mixed in a great variety of ways to produce a great variety of rocks.

Most of the mineral grains in most of the igneous rocks have straight or jagged edges. This helps us tell the igneous rocks from specimens of another great "race" of rocks that we shall study later, in which the mineral grains are rather generally rounded.

Exercise. Examine again the mineral grains in each specimen of your rock collection. Put in one group all specimens that have a large number of straight- or jagged-edged mineral grains. Mark the group "Igneous Rocks."

Granite, a Coarse-grained Igneous Rock. Granite is one of the commonest rocks in the earth. The foundations of every continent are believed to be largely granite. Though covered with soil and other kinds of rock in many places, granite is often exposed at the surface of the earth. It is especially common in mountain ranges, where the covering of soil and other kinds of rock has been stripped off by rain and running water.

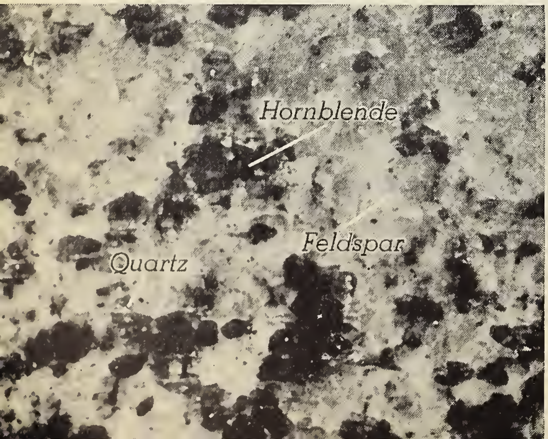
We can all study granite, even those of us who live in regions where granite is not "native." Granite is one of the most widely used building stones in the world. The courthouse or post office of your town is likely to be built, at least in part, of granite. At least some of the monuments in the cemetery are almost certain to be granite.

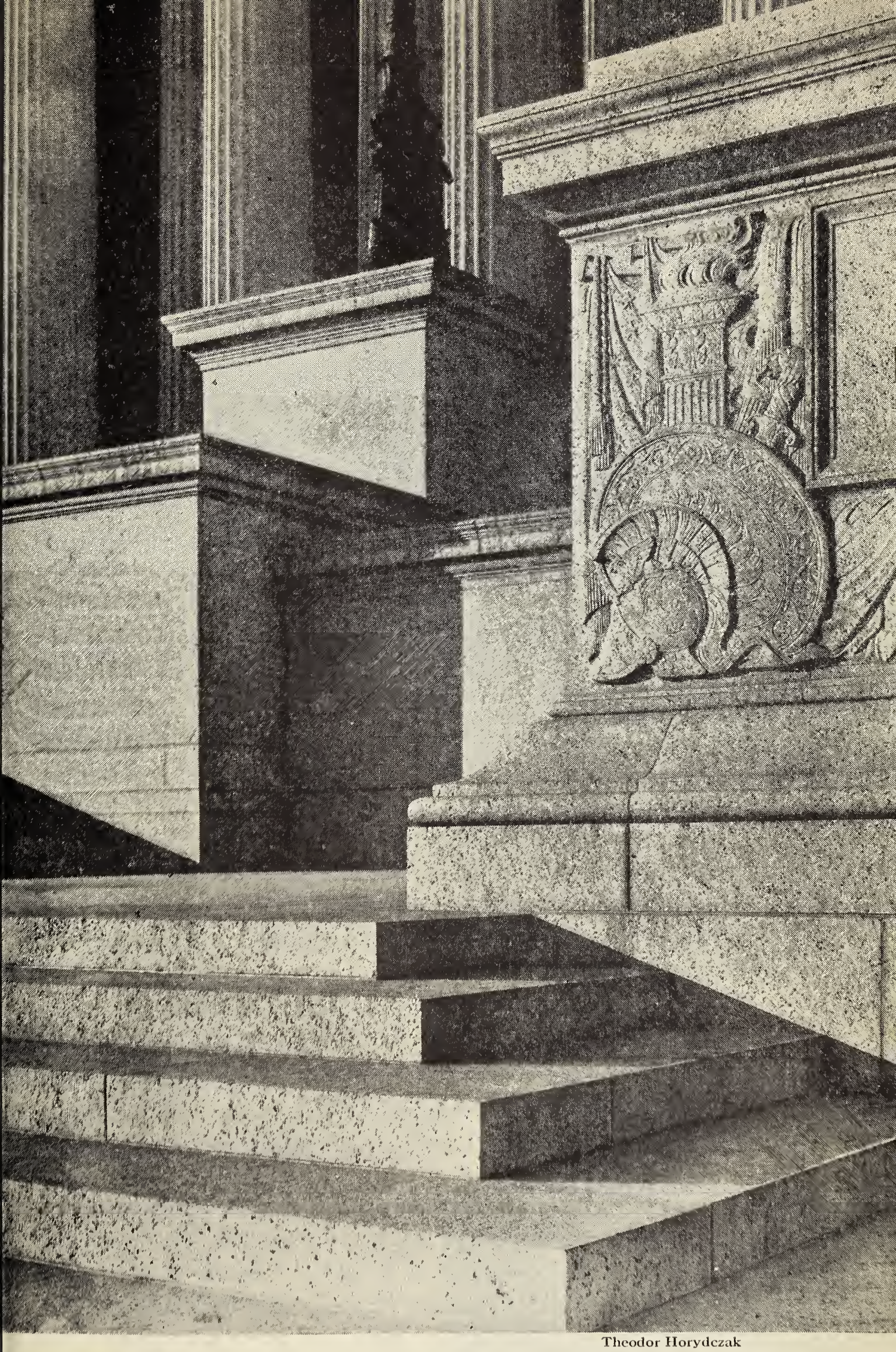
The first thing you will probably notice when you look carefully at an ordinary piece of granite is its coarse texture (see illustration below). All the mineral grains are large enough to be seen by the naked eye. The second thing you will probably notice is that not all the grains are alike in color, size, or other qualities. The different grains give granite a speckled "salt-and-pepper" appearance.

You will probably be attracted by the brilliant little scaly black or white specks of the mineral *mica*. You can easily pry out the flat scales of this mineral with a knife. Most, but not all, granites contain mica. Many granites also contain a black mineral called *hornblende*. Hornblende is an oblong-shaped mineral that looks like coal. Its surfaces are never so smooth and shiny as those of mica.

All granites *without exception* contain feldspar and quartz. *Feldspar* is a common white, gray, or pink mineral with fairly flat and shiny surfaces. *Quartz* is a common *clear* white, pink, or blue mineral. You can tell quartz from feldspar because it is trans-

This magnified specimen of granite shows the different minerals of which it is composed





Theodor Horydczak

ıe entrance to the United States Archives Building in Washington is made of granite. Notice the typical "salt-and-pepper" appearance of the stone parent and because it looks like glass. If feldspar and quartz are not present in a rock, the rock cannot be granite. If they are present, the rock is almost certainly granite no matter what other minerals are present.

Mica is a smooth, brilliant, black or white mineral

Exercises. Study your rock collection and see if you have any specimens which contain both feldspar and quartz. These specimens are probably granite and should be so marked.

Go on a "granite hunt" among the public buildings of your town or city. See how many different kinds of granite you can find. Make a table in which you describe the characteristics of the minerals in each example you find. Remember that rocks which are parts of buildings must be studied by observation rather than experimentation. Do not mark them with pencil or knife or harm them in any other way.

Perhaps you will find certain coarse-grained igneous rocks in your collection which are not granite. Some coarse-grained igneous rocks lack feldspar; others lack quartz. Such rocks are "first cousins" of granite.

Exercise. Place all your coarse-grained igneous rocks which are not granite in a group by themselves, and mark the group "First Cousins of Granite." Write descriptions of each specimen, telling exactly why it is not granite.

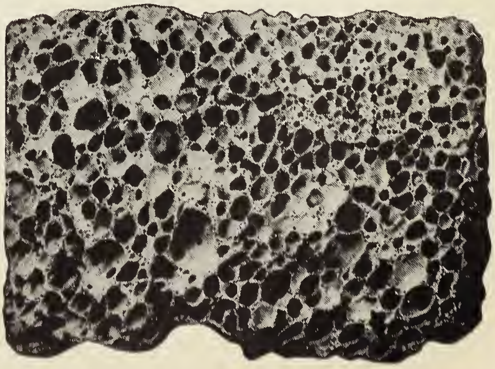
Fine-grained Igneous Rocks. Most coarse-grained igneous rocks, like granite, are believed to have been formed far beneath the surface of the earth. The rocks and soil above them made a blanket through which their heat escaped very slowly. In this way the mineral grains were able to grow large before they stiffened into solid rock. It is believed that long ages after the coarse-grained rocks became solid, wind and weather stripped off the blanket and exposed the rocks at the surface of the earth.

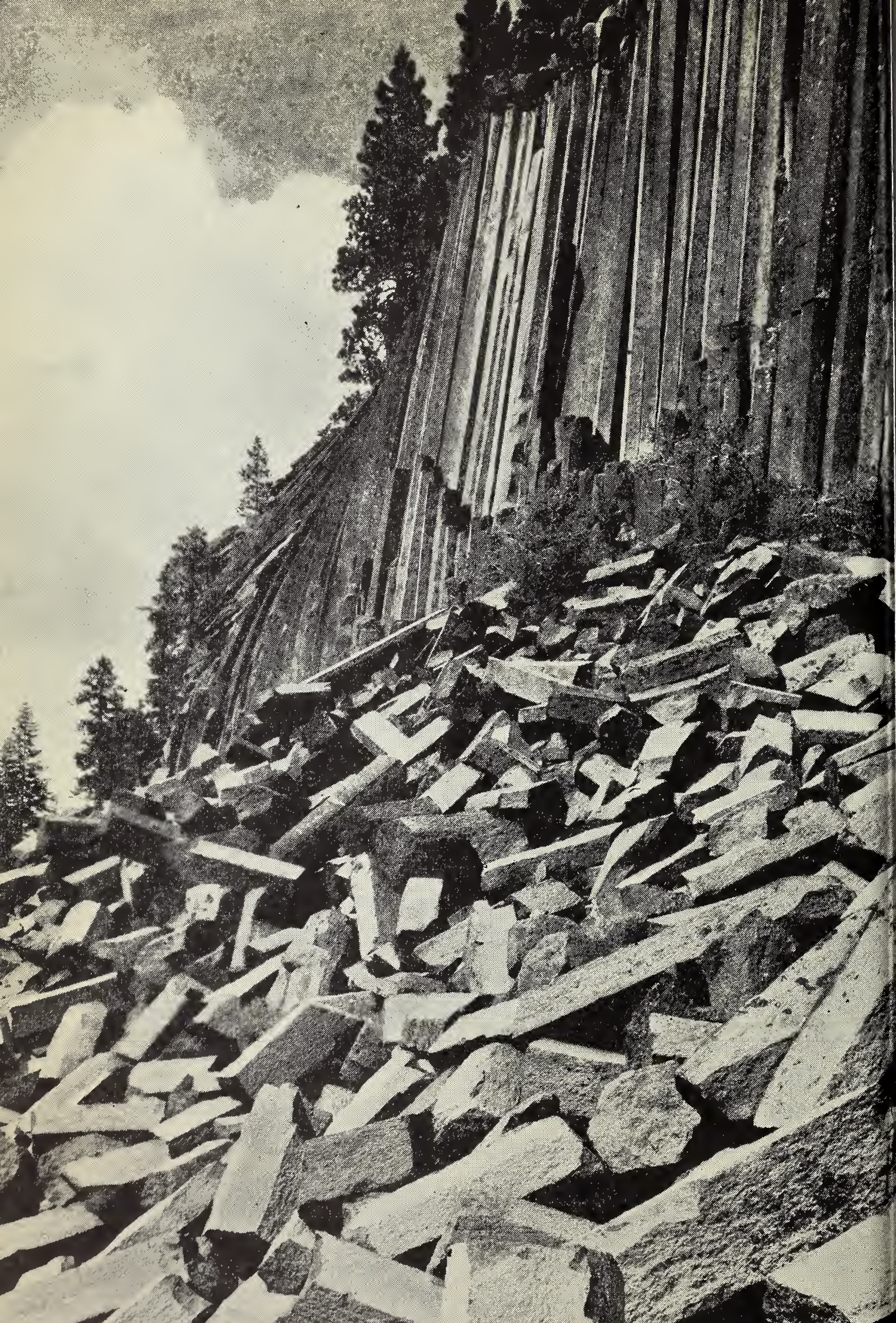
The fine-grained igneous rocks are believed to have been formed in quite a different way. Most of these flowed as liquids through cracks and volcanoes from the interior of the globe. Exposed to the air at the surface of the earth, they had no blanket of rock and soil to keep them warm. The result was that they became solid very rapidly, and the mineral grains did not have time to grow very large. In many of these rocks a magnifying glass is needed to make out the grains.

Fine-grained igneous rocks which have hardened from a liquid at the surface of the earth are known as *lava.* Some lavas are light, some medium, and some dark in color. The commonest lava is very dark brown and is called *basalt* (see page 242). Just as granite is believed to be the foundation of all the continents, basalt is believed to lie beneath all the ocean basins. Much basalt is also found on the surface of the lands.

Have you ever seen clinkers among the ashes from a coal-burning furnace? Clinkers are made of rocky material in coal which will melt but which will not burn. They are irregular in shape and full of holes. Some

Escaping gases make some lavas look like clinkers from a furnace





National Park Service

This is the Devil Postpile in California, made of the dark lava, basalt.

This rock frequently cools in the form of six-sided column lavas look much like clinkers. When freed at the surface of the earth, the gases they contained bubbled out. When the liquid rock turned solid, it was full of holes made by the escaping gas (see page 241).

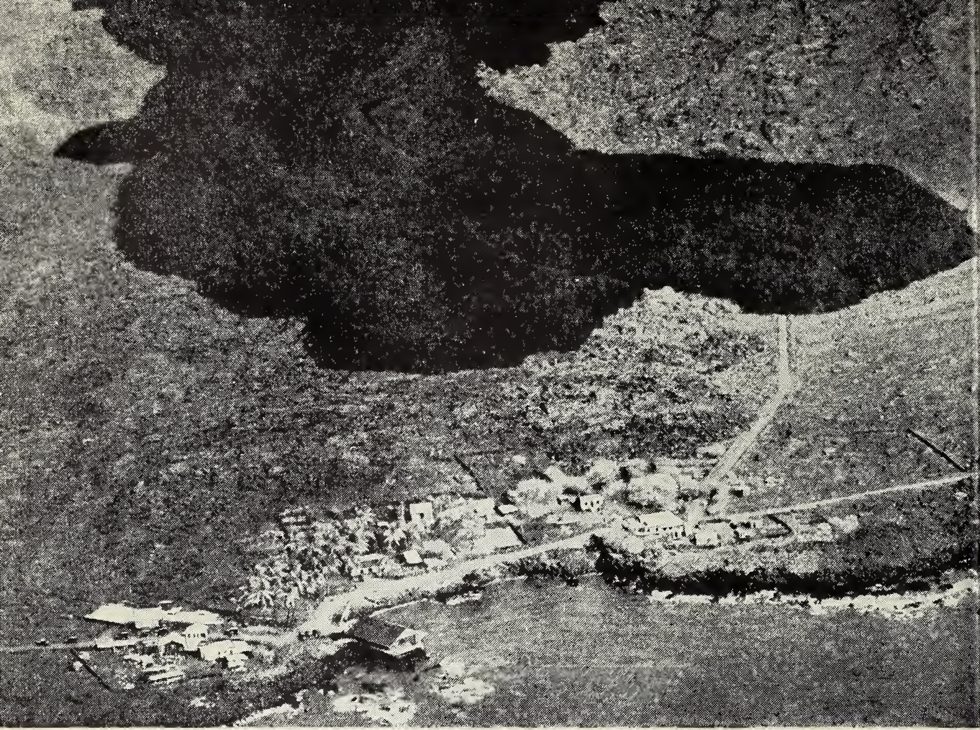
Pumice is a fine-grained igneous rock that looks like honeycomb. It contains more holes than rock. The holes become filled with air as soon as the rock hardens, and the pumice becomes very light. It is not a rare sight to see pumice floating on the ocean after an eruption of a volcano on the shore.

Many fine-grained igneous rocks flow along the ground before they turn solid. On page 244 is a photograph of such a lava flow in the Hawaiian Islands. If you look closely at a rock which was formed in this way, you will see what is known as flow structure. *Flow structure* consists of wavy bands formed by the movement of the rock when it was still soft. Some lavas have a ropy or stringy appearance as a result of their movement, like old-fashioned molasses candy (see page 244).

Exercise. Examine the fine-grained rocks in your collection. If any of them show gas bubbles or flow structure, they are lavas. Even though your specimens come from a region far from any active volcano, they may contain lavas that rose to the surface long ages ago.

Obsidian, a Glassy Igneous Rock. One of the most interesting rocks in the world is the shiny lava *obsidian* (see page 245). This rock is usually jet black, but it may also be gray, brown, purple, green, or red. It is a pure natural glass, and it has the curved shell-like surfaces of broken glass.

Have you ever been to Obsidian Cliff in Yellowstone National Park? If not, you may go there some day and see

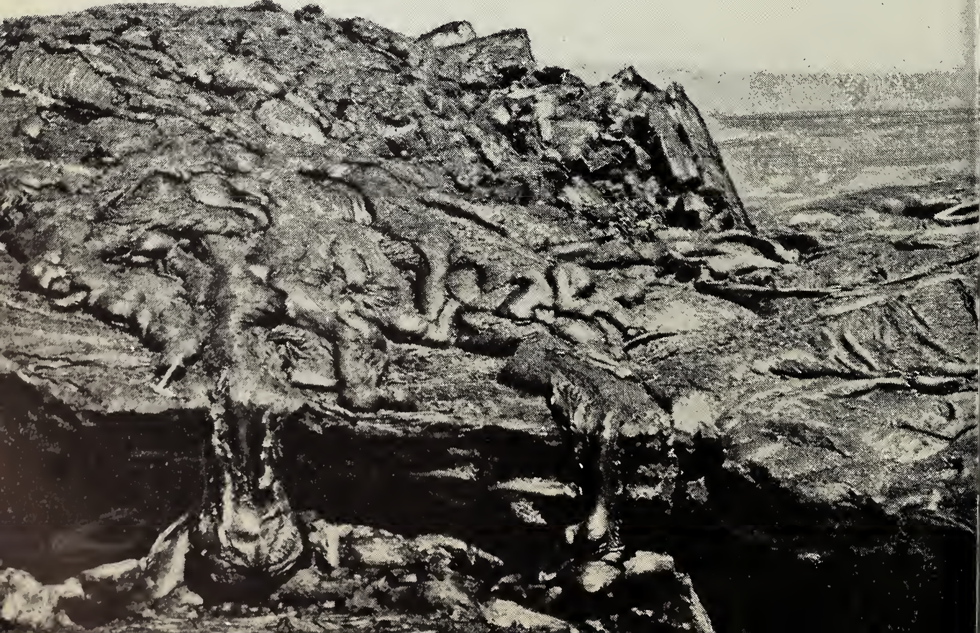


U. S. Army Air Corps

This lava flow in the Hawaiian Islands completely buried the little fishing village and then flowed into the s

When lava does not contain much gas, it may harden with smooth, "ropy" surfac

Photo by R. T. Chamberlin



a whole mountain of obsidian. Indians once made long journeys to Obsidian Cliff to collect material for their arrowheads and knives. Because obsidian is very hard and sharp, it was well suited for the manufacture of cutting instruments in a day when steel was unknown.

Obsidian is natural glass, the finest-grained rock in the world

THE SEDIMENTARY ROCKS

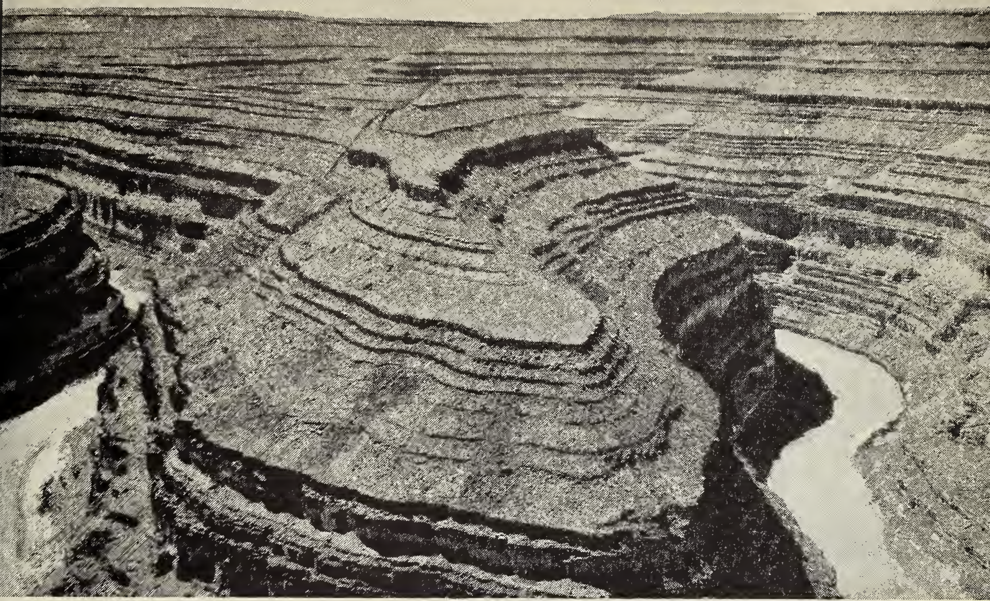
Rocks Are Travelers. If there is a hill near your home, go there the next time it rains. Study the little trickles of water which run down the sides of the hill. Scoop up some of the water in a glass and observe how "dirty" it is. It is filled with mud and sand washed down from the ground above.

The mud and sand were at one time solid rock. The rock was broken up into tiny pieces by the endless attack of the weather. When you found some of the little pieces in the trickle on the hillside, they were in the midst of a long journey from higher to lower ground.

All the pieces of broken rock on the entire surface of the earth are in the midst of the same sort of journey. Most of them are washed downhill by the rain until they reach a steady-flowing stream. Some travel in those strange rivers of ice called glaciers. Some travel on the wind. They often come to rest when the trickles of water dry up, when the streams drop them on the banks, and when the wind dies down. Sooner or later, however, the little pieces of rock take up their journeying again. They do not really stop until they reach the lowest possible place on the surface of the earth. *The destination of most broken rock is the sea.*

Nature as a Builder. Nature is a restless and dissatisfied builder. Scientists believe that she no sooner made the earth from materials taken from the sun than she began to tear it down. She has been remodeling it ever since. But *every time she tears down one part of the earth she builds up some other part.* The broken pieces of rock which are taken away from the high places are laid down in layers in the low places. In this way the high places are torn down but the low places are built up.

With time the layers of broken rock—mud, sand, and gravel—are cemented into solid rock. Earthquakes and other mighty movements have lifted many of these layers of rock from the low places back to the high places. There they are once more exposed to the weather and are once more broken to pieces. Again they are carried to the low places and again they are built into solid layers. Over and



Photograph by Grant, National Park Service

Sedimentary rocks that are cut by rivers reveal their "layer-cake" construction

over in the history of the earth has this mighty cycle of change been repeated through the years.

The change is so slow that we can hardly believe it has happened. But look at the pictures on page 248. The one at the top shows mountains high above the sea. The one at the bottom shows the imprints of creatures which were dug from the rocks in the mountains. The imprints were made by animals that lived in the mud and sand at the bottom of an ancient sea. The rocks of the mountains are that same mud and sand, hardened and lifted high in the air after millions of years!

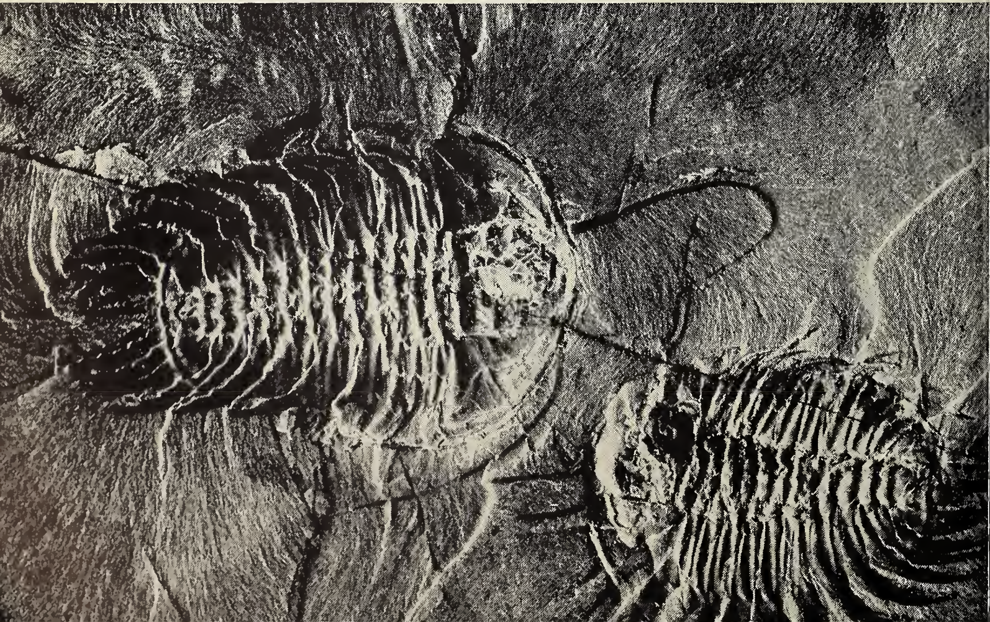
Rocks which are made of hardened mud, sand, or gravel are called *sedimentary rocks.* Sediment is anything that settles out of air or water. Most, but not all, sedimentary rocks were formed under water. Perhaps the most striking characteristic of sedimentary rocks is that they are made of layers (see above).

Sawders

These mountains in the Canadian Rockies were once sediment at the bottom of a s

The impressions of creatures that once lived in the sea
may be found in the rocks of high mountai

Smithsonian Institution



THE SEDIMENTARY ROCKS

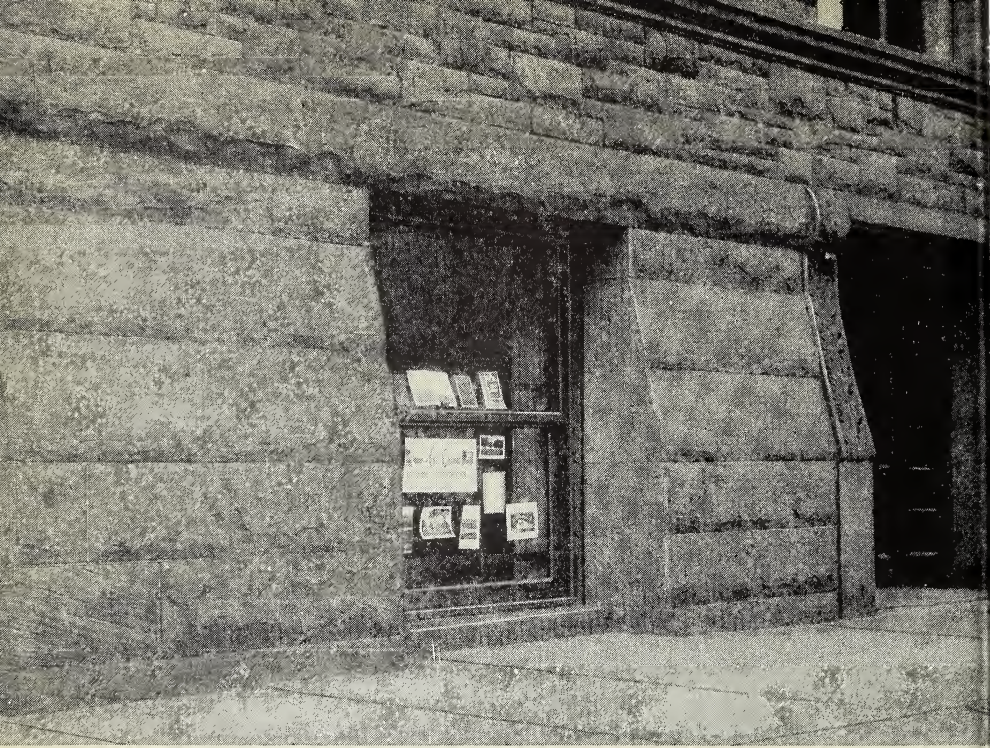
The sedimentary rocks are the second great "race" of rocks. Though they are only a relatively thin skin on the outside of the globe, they cover more of the surface of the earth than do any other "race" of rocks. They will probably be the most common rocks in your collection.

How to Recognize the Sedimentary Rocks. The mineral grains of most sedimentary rocks have been carried by moving water, ice, or wind. In their travels the sharp and irregular edges of the grains were rubbed and bumped until they became smooth and curved. Because of this, *specimens of sedimentary rocks may be told from specimens of all other kinds of rocks by the rounded edges of their mineral grains.*

Exercise. How to separate sedimentary rocks from other rock types: Examine the specimens in your rock collection again. Look for specimens in which the mineral grains seem to have had their edges rounded by rubbing. Mark this group of specimens "Sedimentary Rocks."

Coarse-grained Sedimentary Rocks. One of the commonest varieties of sedimentary rock is known as *sandstone* because it is made of sand which is held together by some cementing material (see page 250). Most, but not all, sandstones are fairly coarse-grained but not so coarse as the coarse-grained igneous rocks.

Most of the sand in most sandstones consists of quartz which came from broken pieces of such igneous rocks as granite. Some sandstones contain a little hornblende, feldspar, and mica. Many sandstones are yellow, brown, or red because there is iron in the cement that holds the sand grains together. If a sandstone is white or gray and very hard, it is probably cemented by a tough, colorless substance called



The Minneapolis Public Library is made of sandstone

silica. If you can rub some of the grains of sand from a white or gray sandstone with your fingers, the cement probably contains *lime.*

Exercise. How to classify sandstones: Make a descriptive table for the sandstones in your rock collection, similar to the table on page 235, but more complete. On the opposite page is a sample of the kind of observations your table should contain.

Irregularly-grained Sedimentary Rocks. In most sandstones the grains in any given specimen are nearly all the same size. The picture on page 252 shows a piece of sedimentary rock in which some grains are very much larger than others. The large grains, indeed, are really not grains at all, but pebbles. The rock is known as *conglomerate* because it is

Specimen	**Grain**			**Cement**		
	Kind	*Size*	*Shape*	*Color*	*Strength*	*Probable Material*
A	*All grains are of quartz*	*Large for sand*	*Edges rounded but grains a little irregular*	*Red*	*Fairly weak*	*Iron*
B	*Chiefly quartz but a few other unknown minerals*	*Average-sized for sand*	*Very well rounded; very nearly perfect spheres*	*White*	*Very weak; crumbles in hand*	*Lime*
C	*Chiefly quartz but also some hornblende and mica*	*Small*	*Poorly rounded*	*Gray*	*Very strong; can hardly be broken with hammer*	*Silica*

a mixture, or "conglomeration," of several different kinds of rocks and minerals. Conglomerates are rock puddings and are sometimes called "pudding stones."

Exercise. If you have any conglomerates in your rock collection, describe them in a table similar to the one you used in describing your sandstones.

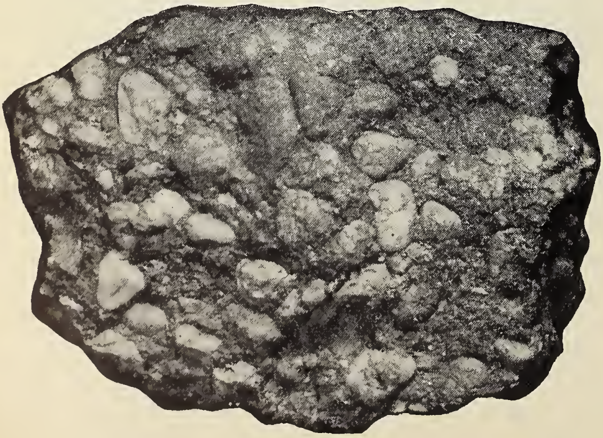
Fine-grained Sedimentary Rocks. When very fine bits of clay or mud are pressed or cemented together, they form a rock which is known as *shale* (see opposite page). Shale is generally very thinly layered. It is easy to split a specimen of shale into thinner and thinner layers.

Shales are usually blue, gray, or black, but some are red. They are made chiefly from the feldspar grains of igneous rocks which have been changed to clay. The grains of clay in all shales are very small. Some shales contain a little sand, and most have some lime in their cement.

Exercise. Make a descriptive table for the shales in your rock collection similar to the tables used in describing your sandstones and conglomerates.

Limestone. One of the commonest of all sedimentary rocks is known as *limestone. It is not formed from broken pieces of rock but from mineral matter dissolved in sea water*. Limestone is a compound of ordinary lime and carbon dioxide. It forms as a soft deposit, or "ooze," on the bottom of the sea and is later hardened and raised above the water (see page 255).

Pebble rocks are called conglomerates



Limestones are softer than most rocks and are easily scratched by a knife. Their range in regard to grain and color is varied, but they all may be recognized with the help of a little acid. *An acid is a material, like vinegar, which is sour or biting to the taste.* Acids can turn certain compounds into other compounds. With the help of hydrochloric acid (a combination of the elements hydrogen and chlorine) limestone may be so changed that some of the carbon dioxide gas escapes.

Exercises. How to recognize limestone: Put a drop of dilute hydrochloric acid on the rock which you believe might be limestone. If the drop begins to bubble furiously with escaping gas (carbon dioxide), the rock is limestone.

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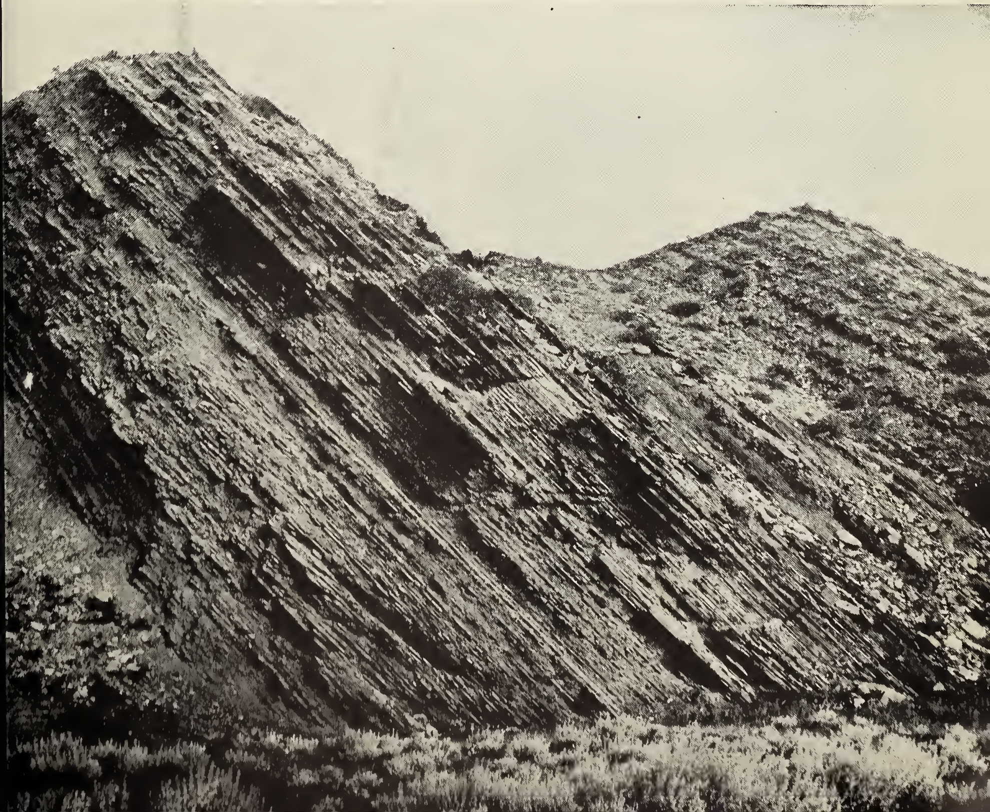
hale in this picture was laid down as mud on the bottom of a sea. It later rdened in thin layers and then was uplifted and tilted by movements in the earth

Photograph by Stanton, U. S. G. S.



Be careful not to spill any acid on your books or clothing, because it will eat holes in them.

Go on a "sedimentary-rock hunt" among the public buildings of your town or city. Sandstone and limestone are widely used as building stones, and you should be able to find several varieties of them in regions where these rocks are native. Make a descriptive table of your discoveries. Remember not to harm the buildings in any way.

THE METAMORPHIC ROCKS

The Effects of Pressure on Rocks. We have already seen that the crust of the earth is not so quiet and firm as it generally seems. Earthquakes and broad warping movements have made great changes in the landscape in the course of two or three billion years. Some rocks have been crumpled like paper as a result of these movements. Some rocks have been melted by the heat which is always born of terrific pressure, and been made to flow like molasses (see page 256).

Extreme pressure and heat produced by earth movements may change the mineral makeup of rocks. Rocks so changed are known as *metamorphic rocks.* "Metamorphic" is a combination of two Greek words which means "to change from one form to another." It makes a rather difficult English word, but it tells better than any other word the chief fact about this third great "race" of rocks.

Any igneous or sedimentary rock that suffers sufficient pressure will turn into a metamorphic rock.

Common Metamorphic Rocks. When granite is changed by pressure and heat, it becomes a rock called *gneiss* (see

Ewing Galloway

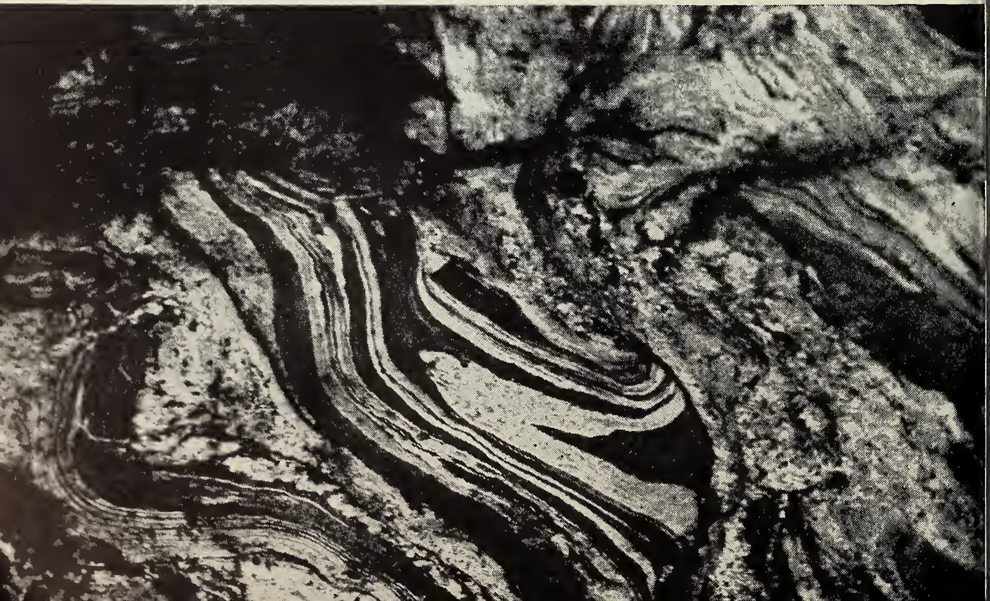
R.C.A. Building, Rockefeller Center in New York City, is made of the beautiful Indiana limestone picture below). Notice the alternating light and dark bands of minerals. The granite has lost its "salt-and-pepper" appearance because its minerals have been rearranged. The light bands are the quartz; the dark bands are the feldspar, hornblende, and other minerals. Any rock that is banded in this fashion is a gneiss.

When sandstone is changed by pressure and heat, it becomes a *quartzite*. This is the strongest rock in the crust of the earth. When a specimen of quartzite is broken by a hammer, the crack runs *through* the grains of sand as well as around them. Because of this you may easily tell quartzite from sandstone. In a broken piece of sandstone the crack runs *around* the grains but never through them.

When shale is changed by pressure and heat, it becomes a *slate*. Slate is harder than shale, and it breaks into layers with much smoother surfaces. That is why slate is so well suited to the manufacture of shingles. The photograph on page 257 shows a house which is being well defended against the weather by slate.

Pressure and heat may make hard rocks flow like molasses. This rock was changed by pressure and heat from a granite to a gn

U.S.G.S.



Keystone

Slate makes good shingles because it breaks with very smooth surfaces

When limestone is changed by pressure and heat, it becomes *marble*. This rock, like limestone, is fairly soft and is readily attacked by acid. It always has much larger grains than limestone. It is frequently clouded or veined by impurities, as is shown on page 258. This clouding and veining make marble a very beautiful stone and one of the best materials for decorating the interiors of buildings.

Exercises. Make a descriptive table for your metamorphic rocks, as you did for your sandstones, conglomerates, and shales. Try to determine what kind of rocks your specimens were before they were changed by pressure and heat.

Go on a "metamorphic-rock hunt" among the public buildings of your town or city. You should find a variety of slates and marbles there. Make a descriptive table of your discoveries. And remember: do not mark or mar any building.

Summary. You have now come to the end of your study of common rocks. You have learned that *every rock is a mixture of minerals.* You have learned that though many of these mixtures occur in nature, all of them fit into one or another of three great "races," or classes, of rocks.

In studying the commonest members of the three great "races" of rocks you should have become acquainted with some of the following minerals and rocks:

Limestone that has been changed into marble makes a beautiful ornamental stone

Horydczak

Minerals	Igneous Rocks	Sedimentary Rocks	Metamorphic Rocks
Mica	Granite	Sandstone	Gneiss
Hornblende	Basalt	Conglomerate	Quartzite
Feldspar	Pumice	Shale	Slate
Quartz	Obsidian	Limestone	Marble

Not all these members of the world of rock are likely to occur in your collection. But by going on hunts through public buildings you will find many kinds of rocks that your own collection lacks. In one way or another you should be able to become acquainted with most of the rocks described in this chapter without leaving your own neighborhood.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. It is difficult to learn about rocks without the help of a museum.

2. There are so many different kinds of rocks that only a trained scientist can tell one kind from another.

3. The "texture" of a rock means its hardness with reference to other rocks.

4. The earth is so old and cold that there are no longer any signs that it once was very hot.

5. The mineral grains which make up the igneous rocks always have rounded edges.

6. Coarse-grained igneous rocks have cooled more rapidly than fine-grained igneous rocks.

7. All granites contain mica.

8. "Lava" is another name for granite.

9. The minerals which make up the sedimentary rocks always have straight or jagged edges.

10. "Shale" and "slate" are two names for the same rock.

11. If acid is dropped on quartzite, it will bubble furiously as carbon dioxide escapes from the rock.

12. When granite is changed by pressure and heat, it becomes marble.

13. Every mineral is a mixture of two or more rocks.

Questions for Discussion

1. Discuss the rocks which you have observed in use as building stones. Try to determine the merits of each kind of rock as a building stone.

2. Why do you suppose marble is used more for decorating the inside of buildings, and granite more for the outside?

Things to Do

1. Shake up a handful of soil in a milk bottle half full of water. Observe how the sediment settles to the bottom. Do the coarser particles separate in layers from the finer particles? This experiment will help explain how sedimentary rocks are formed.

2. See if there is anyone in your town or city who makes a hobby of collecting rocks. He will probably be happy to show you his collection and tell you about what it contains.

3. If there is a museum in your vicinity, visit it and look up the rock collection. Try to see how many rocks and minerals you can name *before you read the labels.*

4. If you have found any rocks and minerals that you cannot name with the help of this chapter, look up *Field Book of Common Rocks and Minerals*, by F. B. Loomis. This is a simple guidebook for the amateur collector.

Ewing Galloway

Good black soil, the gift of the rocks to man

CHAPTER ELEVEN

What Is Soil?

HOW SOIL IS MADE

The Importance of Soil. Of all the stony material in the crust of the earth, that which is known as soil is the most important in our lives. Most of our houses are built on soil. Most of our food comes from plants that live in the soil and from animals that live on the plants.

In the last chapter we learned that rocks are forever being broken into tiny pieces and moved from higher to lower places on the surface of the earth. We learned that this journeying of the rocks is very slow. The bits of rock often stop to rest in the midst of their travels. They gather together into great sheets of loose earthy materials which cover vast areas on every continent. *These sheets of loose earthy material are called soil.*

The Eternal Hills. Poets have long sung of the "eternal hills." When we look at the calm, stern face of a mountain, it indeed would seem capable of lasting forever. But when we *study* the faces of mountains and hills, we find that they are far from everlasting. Scientists know that whole mountain ranges have been built up and torn down *many times* during the long, long course of earth history. Mountains have many enemies which gnaw at them as a mouse gnaws at a piece of cheese. Given enough time, the enemies will win; the tallest mountains will be nibbled away. What are these enemies that make the "everlasting hills" so far from everlasting?

The Weaknesses of Rocks. One of the enemies of the rocks lies right in the rocks themselves. Some rocks are very hard and resist very well any attacks that are made upon them. Quartzite, as we learned in the last chapter, is such a rock. Many other rocks, however, are weak. Some, like poorly cemented sandstone, crumble in your hand. Some, like limestone, are easily dissolved by the acids which rain may carry into their pores and cracks.

Acid as an Enemy of Rock. One of the most interesting sights in the world results from the weakness of limestone when attacked by water in which some acid is dissolved. In Kentucky, Virginia, New Mexico, and many other places, great underground caverns have been made in this way. The acid that dissolved the limestone rocks to make these caverns is none other than our old friend carbon dioxide. Rain absorbs some of this gas from the air, and then carries it into the ground through the pores and cracks in the rocks. When dissolved in water, carbon dioxide forms *carbonic acid*, a very weak acid, to be sure, but capable of forming such a scene as you see on page 264.

The acid water which hollows out caverns in limestone becomes loaded with the lime it has stolen from the rocks. Such water sometimes drips from the ceilings of caves. In doing so it evaporates and gives back some of the lime in the form of strange formations which look like icicles. Such a rock icicle on the ceiling of a cave is called a *stalactite*. When water drips from a stalactite to the floor of the cave, a blunter icicle (*stalagmite*) grows up from the floor (see page 264).

Even hard rocks like granite are slowly worn away by acid-bearing waters. Rain water containing carbonic acid will slowly eat into granite and certain other rocks. Some

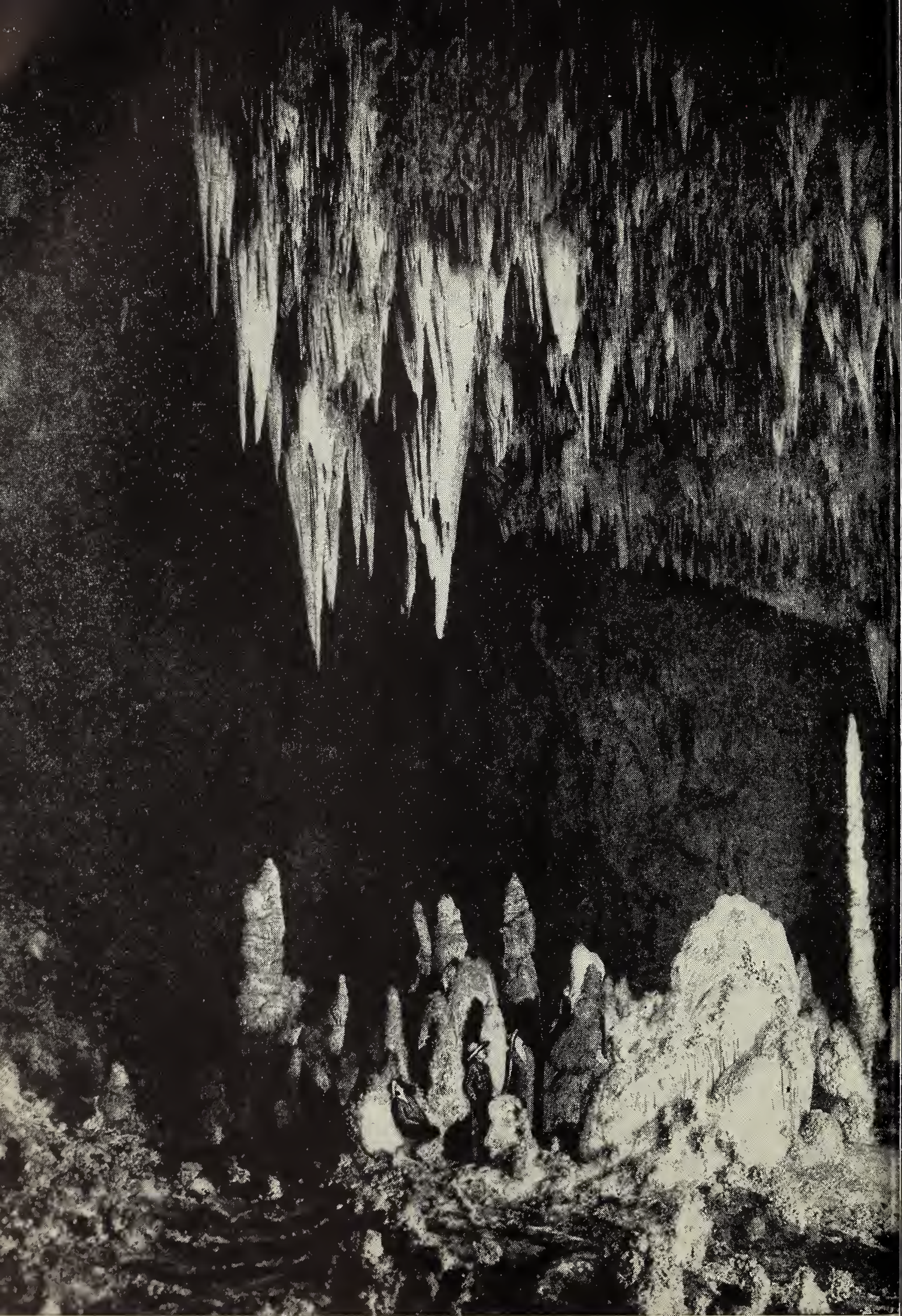


Photo by Kemp, Atchison, Topeka & Santa Fe Railway

Carlsbad Caverns in New Mexico are a mighty monument to the weakness of limeston
when attacked by acid-bearing waters. Can you find the stalactites and stalagmites

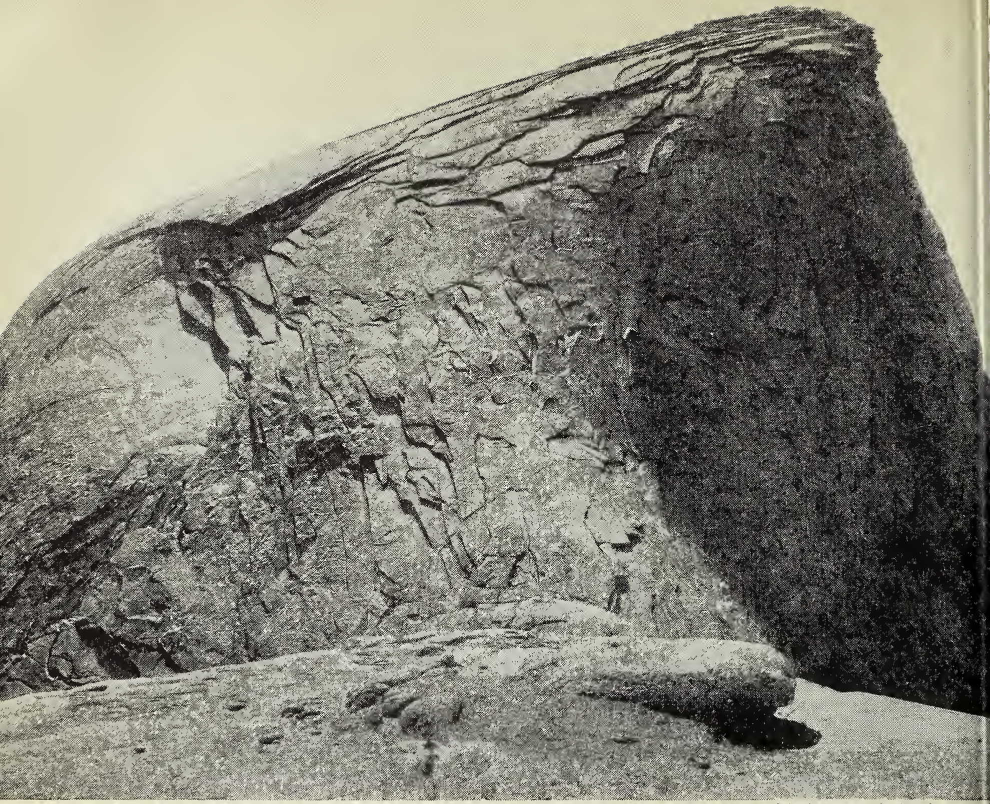
of the minerals of these rocks slowly dissolve in the water and are carried away.

Heat and Cold as Enemies of Rock. In many places rocks are broken by changes in temperature. *All rocks expand when heated and contract when cooled.* As heat and cold come and go with day and night, the outer portions of rocks expand and contract. This action, combined with the action of acid-bearing waters, makes their surfaces break and peel off (see page 266).

Freezing Water as an Enemy of Rock. No enemy of the rocks is more powerful than freezing water. When water freezes in the cracks of a rock, it exerts a tremendous pressure. In Unit II we saw what this pressure does in the radiator of an automobile. It does the same thing to a rock. Many rocks are broken or pried apart by water freezing in their cracks (see page 267).

Growing Things as Enemies of Rock. Small bits of rock which have been formed in one way or another by the enemies of rock may collect on a mountain side as a small deposit of soil. A seed carried on the wind may fall on this soil. It may take root, sprout, and become a growing tree. As the tree grows larger, its roots go deeper and deeper into the soil. Soon they enter some of the small cracks in the rocks underneath. Like water freezing in a crack, the roots of the tree exert tremendous pressure. Gradually they may push the rock apart, as in the picture on page 267.

Smaller plants than trees are also enemies of the rocks. Many rocks are covered with flat gray scaly plants called *lichens*, as shown on page 267. Lichens can perform the marvelous feat of living on solid rock. They break down the rocks slowly as they eat them.



National Park Service

Day and night changes in temperature are helping to peel off the surface of this mounta

Glaciers as Enemies of Rock. Many of the earth's high mountains are capped by great fields of snow throughout the year. Tongues of ice called *glaciers* reach down into the valleys on the mountain sides from these summit snow fields. Under the great weight of the snow above them the glaciers are squeezed into ice and slowly pushed down the mountains. The ice flows very slowly indeed, in many cases only a few feet in a year.

In spite of their slow motion, glaciers are among the most powerful enemies of the rocks. As they move they tear boulders from the mountains. These boulders scrape against the rock surface over which they are moved. The grinding action of rocks frozen in the ice of a glacier is enormous. Great quantities of rock are ground into bits and carried along until the ice melts where it meets the warm air of lower altitudes.

Some of this glacial freight is left at the edge of a melting glacier. The photograph on page 268 shows such a deposit. Some of the rock material is carried down the mountain by the rushing water which forms as the glacier melts. When the water reaches the foot of the mountain,

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ater freezing in the cracks of rocks can split and pry them apart. B, roots of trees, frost, exert a mighty pressure. C, lichens on rocks help to crumble them away. D, glaciers supplied the material for this fence

Sawders

Broken rock carried from above is dropped at the foot of a glacier

it moves more slowly. There the smaller particles of rock drop to the bottom and help to form the soil of the valley.

At one time all the northern part of the United States was much colder than it now is. It was covered by great glaciers which had moved south from the Canadian highlands. Now these glaciers have melted away, but you can see many boulders and much gravel which they have dumped on the land. The picture D on page 267 shows the edge of a farm over which a glacier once passed. The farmer has built his fences of boulders which were dropped by the ice.

The Enemies of Rock Are Our Friends. All these forces that break up solid rock into little pieces and scatter them over the lands are our friends. They make the soil without which we could not live.

THE NATURE OF SOIL

Soil in General. Before we try to discover how one kind of soil may differ from another kind, let us try to find out in what respects all soils are alike. In this way we shall get a general idea of what soil is. This is necessary before we can learn the differences between particular kinds of soils.

Soil Is Largely Broken Rock. You have been told that all soils are produced by the enemies which break solid rocks into little pieces. If this is true, you should be able to recognize these little pieces of rock in a sample of any kind of soil.

Exercises. How to prove that soil contains small pieces of rock: Get a sample of soil from a flowerpot or from the schoolyard. Place a teaspoonful of the soil in a test tube and nearly fill the tube with water. Shake well. Place a drop of the muddy water on a glass slide and examine it under a microscope. Do you see any particles that look like little broken pieces of rock? Do you see any flat shiny particles that look like mica? any glassy particles that look like quartz?

If the soil contains heavy particles that settle quickly to the bottom of the test tube, pour off the water and spread the sediment thinly on a piece of paper. When dry, examine the particles with a magnifying glass. Do any of these resemble any of the minerals or rocks which you studied in the last chapter?

Soil Contains Humus. Perhaps you have noticed that the soil in gardens and plowed fields is likely to be very dark in color. Let us see if we can discover what makes it so.

Exercise. Get a sample of the darkest soil you can find in your neighborhood. Place part of the sample in an iron dish and heat it for several minutes over a hot flame, as shown on the opposite page. Can you see any fumes rising from the dish? Can you make out an odor of something burning? Does the heated soil change color?

The dark color of the soil is caused by the presence of decayed plant and animal material, which is known as *humus*. Unlike the stony material of soil, humus can be burned. Most soils contain some humus. Good soil contains a considerable amount of humus. Plant life cannot thrive in soil which is poor in this material. We shall learn why in the course of our study.

Soil Contains Water. What happens to the rain, snow, dew, and other forms of moisture that settle on the surface of the earth? Do they completely run off into the oceans and evaporate into the air? Or does some of this moisture find its way into the soil?

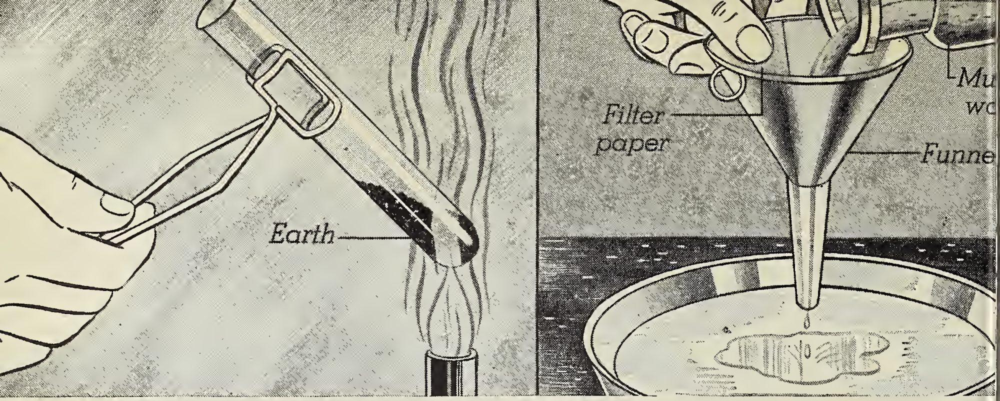
Exercise. How to prove that there is moisture in soil: Place a teaspoonful of soil in a test tube. Heat the test tube slowly in a weak gas flame, as shown on page 272. Does any moisture collect on the inside of the tube? Try the same experiment with some dust from a dry dirt road or footpath. Is there any moisture in this material?

These boys are testing soil for humus

If all the soil in the world should suddenly lose its power to hold moisture, all land plants would shrivel up and die. All the animals that live on the plants would also die. The earth would turn into a desert. This world-wide desert would be more "deserted" than any desert is today. The soils of even the driest deserts contain a little moisture, enough to keep alive a scattered population of plants and animals.

Soil Contains Air. On page 162 we performed an experiment which proved that there is air in soil. If you do not remember this experiment, perform it again.

Air is trapped in the spaces between the little particles of broken rock and humus. It is as necessary as moisture to the health of growing things. Later in this chapter we shall learn exactly why. *Good soil contains spaces between its particles which take up as much room as the particles*



Left: how to test soil for moisture. Right: how to test soil for soluble mineral ma

themselves. These spaces are filled with moisture and air, which are so necessary in the lives of land plants.

Soil Contains Soluble Mineral Matter. Do you remember from our study of the water supply on page 107 that drinking water may have tiny invisible particles of mineral matter dissolved in it? Do you think that soil or the moisture in soil might contain similar soluble particles of mineral matter? You can find out by the same methods you used in your experiments on drinking water.

Exercise. How to find out if soil contains soluble mineral matter: Shake some dark soil in a jar of water. Let the heavier particles settle; then pour the water through a filter paper which has been folded and fitted into a funnel, as shown above. Does the water come through clear or muddy? Pour a little of the filtered water into a clean flat dish and allow it to evaporate in a warm place. Is there a coating of mineral matter left on the bottom of the dish? If so, where did it come from?

The soluble mineral matter in soil is one of the chief foods of plants, as we shall see later in the chapter.

The Definition of "Soil." We have now made enough observations and experiments on soil to have a good idea of its nature. From these studies we can define "soil" as *largely a loose mixture of broken rock which contains some humus, water, air, and soluble mineral materials.*

DIFFERENT KINDS OF SOIL

Classifying Soil. Now that we know the general nature of soil, we are ready to try to discover how one kind of soil may differ from another kind. What basis can we use for classifying soil? Since soil consists largely of little pieces of rock, it is usually classified according to the kinds of rock it contains. On this basis there are four common types of soil: *gravelly*, *sandy*, *clayey*, and *loamy*.

Gravelly Soil. Any mixture of coarse sand and pebbles is known as *gravel*. Such a mixture forms the soil on the sides of many steep mountains. Swiftly running rivers may carry gravel and deposit it as soil along the banks when their waters fall.

Plants and the men who raise plants for food do not like gravelly soil. Such soils are stony and hard to plow. They do not readily hold the soluble mineral matter which growing things need for food. They let the rain water leak out because the spaces between the particles are so large. The result is that crops raised on such soil are likely to die of thirst.

Exercise. Explore your neighborhood for gravelly soils. Make a report on the condition of the plants which you find growing in them.

Sandy Soil. In many places the soil is made up very largely of broken pieces of quartz. Such soil is called *sandy*. If the sand is coarse, it has the faults of gravelly soil. If it is fine, it may be able to hold enough water and soluble mineral matter to make farming possible.

Throughout southern United States much of the soil is too sandy for good farming. The valuable mineral foods of plants are washed (leached) out by the rains. They are either carried down into the earth so deep that the roots of plants cannot reach them or they are carried away by the rivers. In Florida, where sandy soils are used for orange-growing, the farmers must replace these lost mineral foods each year. They must spend thousands and thousands of dollars for the soluble plant foods which are known as *fertilizers.*

Exercise. Explore your neighborhood for sandy soils and make a report on them to your class. If possible, talk with farmers who are meeting the problem of sandy soils in a practical way.

Clayey Soil. We learned on page 252 that clay is produced by the breakdown of feldspar. When wet, clay becomes greasy and sticky. The spaces between the tiny particles are themselves so tiny that the water which gets into them is held there like a mouse in a trap. When dry, clay becomes hard and tough. In some cases it forms extremely hard and tough layers, the hated *hardpan* of the well-digger and the farmer.

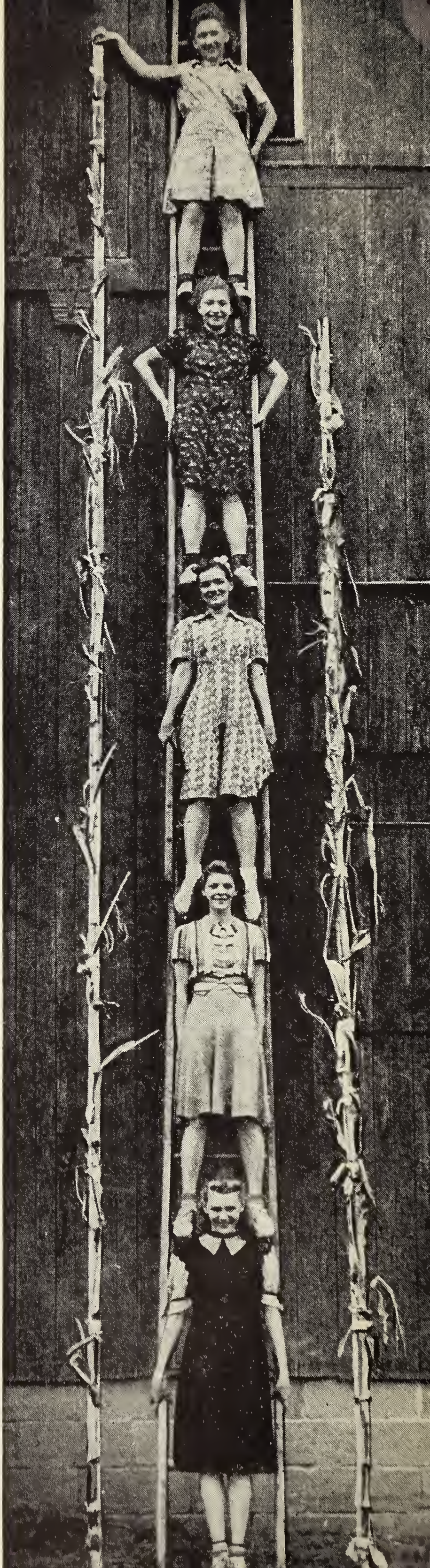
Clayey soil is poor soil. Even when it is rich in plant foods, as is generally the case, it is hard to plow when wet and harder to plow when dry. It is as difficult for a plant to penetrate a clayey soil with its roots as it is for the farmer to penetrate it with his plow.

Exercise. Explore your neighborhood for clayey soils and report on them to your class.

Loamy Soil. A mixture of sand and clay is known as *loam.* Loamy soil is the best of all soils for growing things. It is easy to plow because it is never too soggy or too hard. It holds just enough of the soluble mineral matter, water, and air which are so necessary for plant life. It usually contains some humus too, which is also necessary. Pure sand, pure clay, and pure humus are all bad for growing things. A combination of the three, such as occurs in loam, is best.

Exercise. Explore your neighborhood for loamy soils and make a report on them to your class.

Residual Soil. At the beginning of this chapter we learned that soils are travelers from the higher to the lower places on the surface of the earth. Most soils are therefore not found at their places of birth. Some soils, however, occur right on top of the solid rocks that mothered them. They have not yet begun their travels. Such soils are called residual, which means "sitting back." Residual soils "sit back" while other soils wander.



Charles E. Grayson

Corn grows tall in the loamy soil of the Middle West

The picture below shows a ledge of solid rock which is being broken into bits by its enemies. Notice how the solid rock is covered with loose stones and gravel (the *subsoil*) and how these in turn are covered with rich black soil (the *topsoil*).

The loose material on top of the solid rock in this picture is residual soil. It was formed right where you see it, from rock exactly like that on which it now rests. The enemies of the solid ledge have already broken the upper layers into very fine pieces, which decaying plants have darkened with humus. Under this true soil the enemies are still eating into the ledge, breaking up the rock in the gravelly zone of the subsoil.

Residual soils made from rocks which are rich in quartz are likely to be sandy and poor. Those made from rocks rich in feldspar are likely to be clayey and poor. The best residual soils are made from lava or limestone because these rocks are neither too sandy nor too clayey. When mixed with humus and properly fertilized they are suitable for farming.

Transported Soil. Most soils, as we have said, are not residual. They have traveled from their places of birth. Travel enriches soils as it enriches human beings. It mixes poor sandy soils with poor clayey soils to produce good loamy soils. Soils which have traveled from their places of birth are known as transported soils. They are generally found in the lowlands and residual soils in the highlands.

The soils in this picture lie on top of the rocks that mothered them

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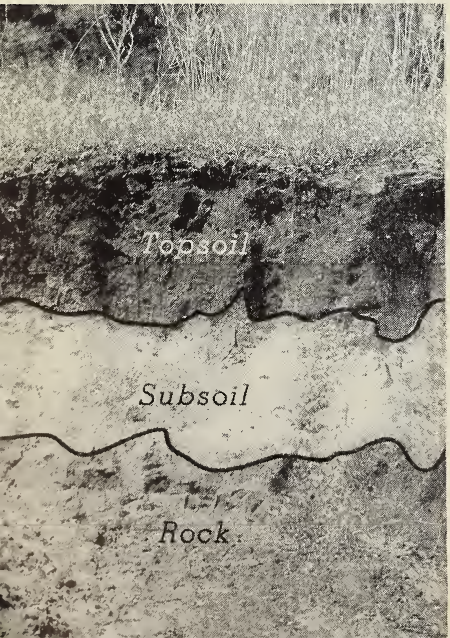
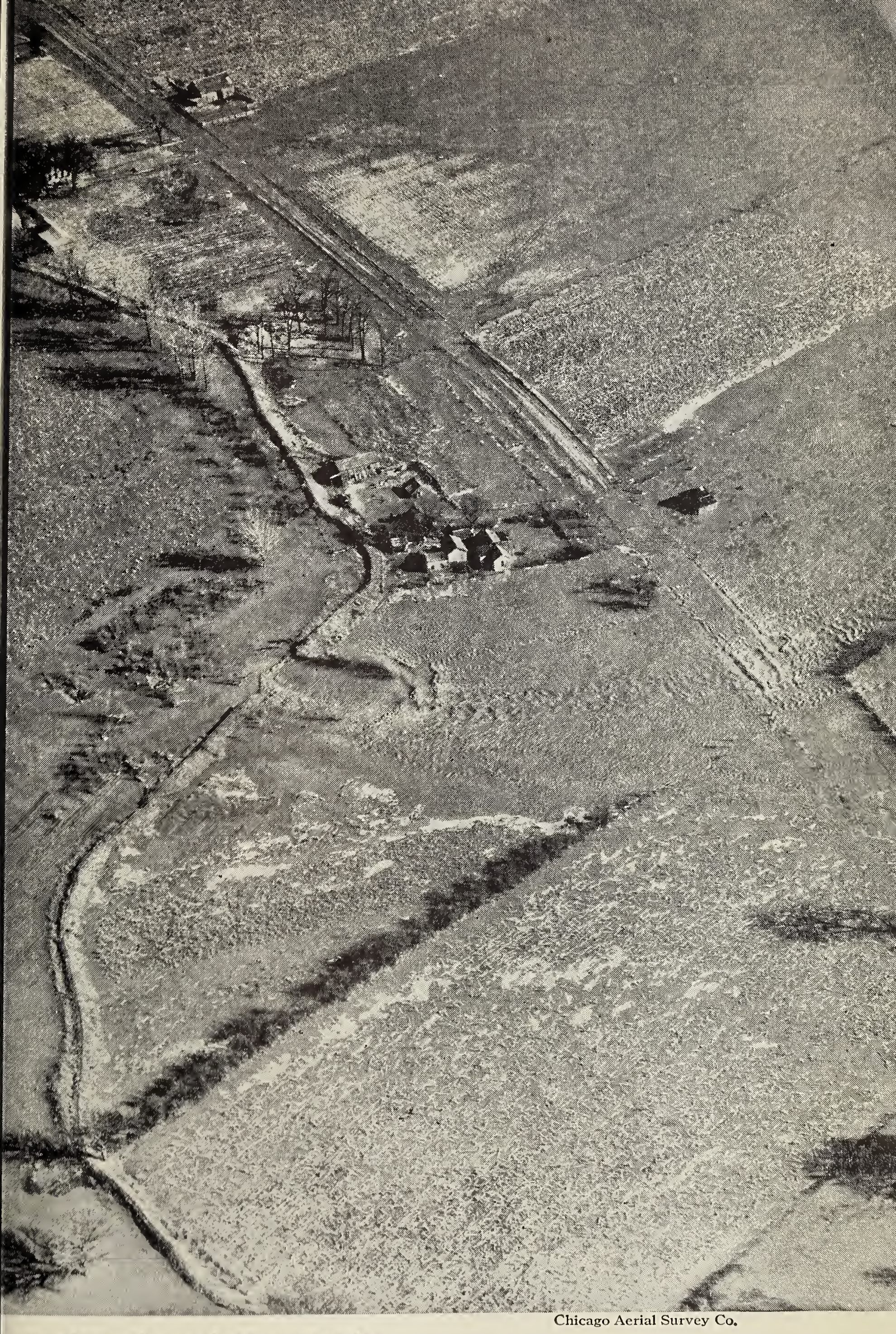




Chicago Aerial Survey Co.

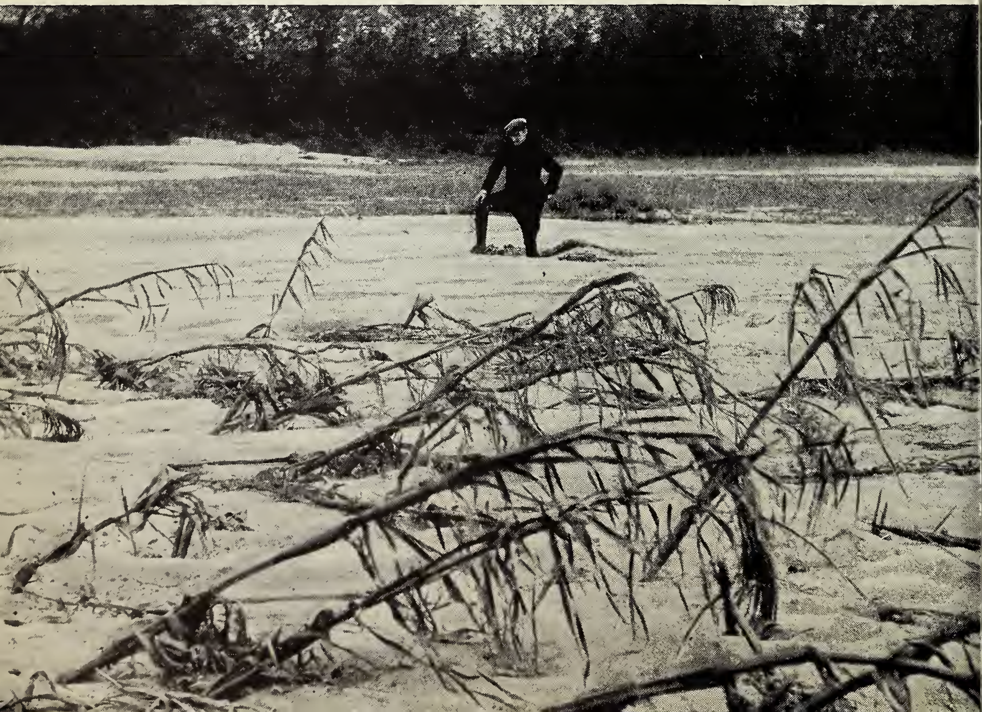
is aerial view shows what a river can do to the country when its waters run wild in flood

Rivers Carry Soil. Have you ever seen a river swollen by flood which has broken over its banks? The photograph on page 277 shows such a river. It is carrying tons and tons of fine sand and clay. It is also rolling larger pebbles of gravel and perhaps some boulders along the bottom, rounding and breaking them as it flows. This rocky material is soil in the midst of its travels.

The picture below shows what happens when a flood dies down. When the river was flooded beyond its normal channel, the speed of the water was checked enough so that much of its cargo of broken rock was dropped on the land. Multiply what you see in this picture by the vast number of brooks and rivers on the earth as a whole, and you will have some idea of the importance of running water in spreading soil over the surface of the globe. River soils are perhaps the most abundant and certainly the richest soils in the world.

Flooded rivers drop their rocky burdens on the land when they return to their normal chann

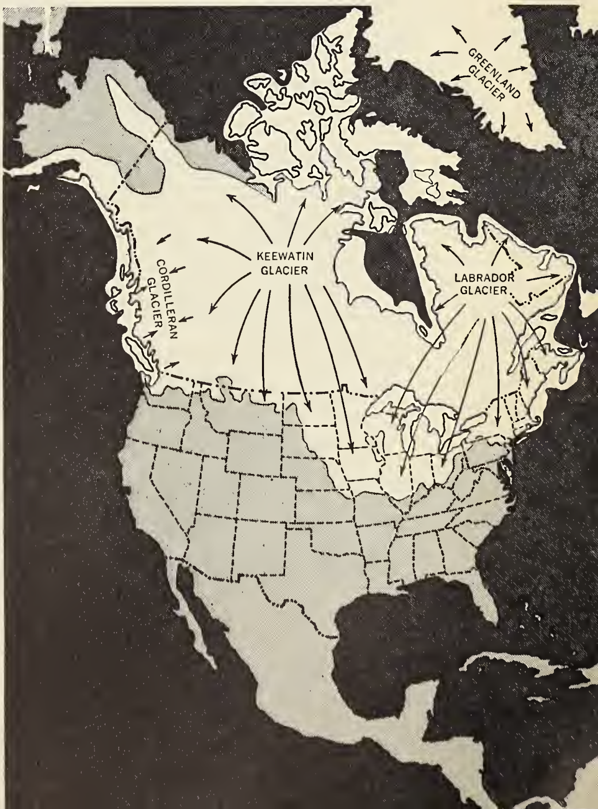
U. S. D. A., Soil Conservation Service



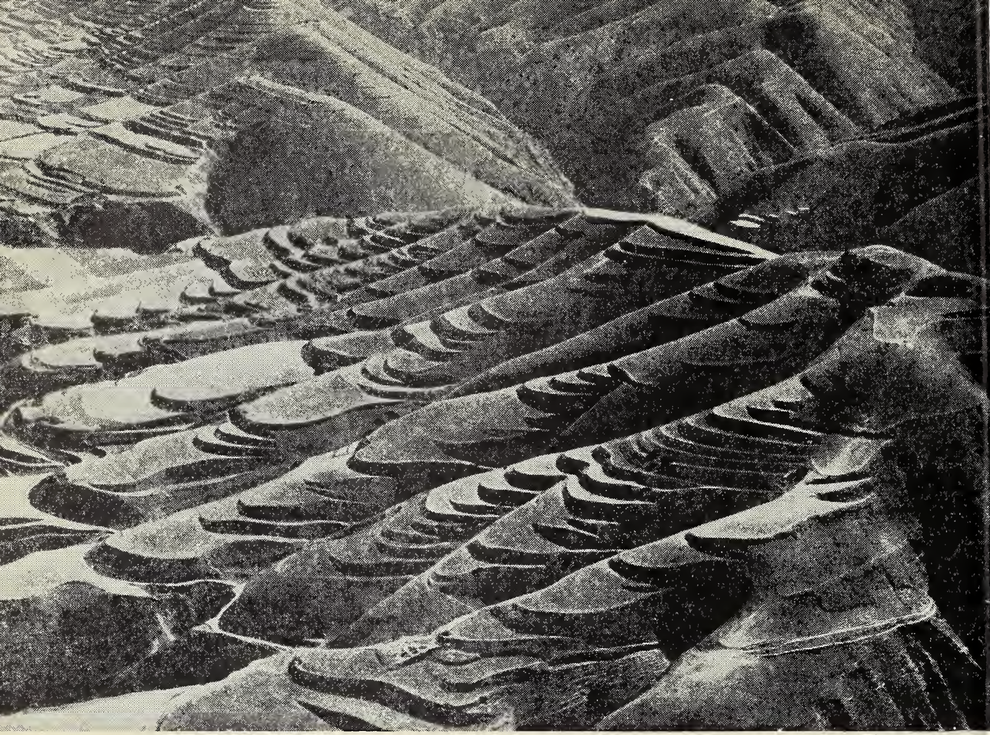
Glaciers Carry Soil. Glaciers not only produce soil by breaking down the solid rocks over which they move, but they drop the soil widely on the land when they melt away. On page 268 we mentioned the fact that at one time all of northern North America was covered by glacial ice. The map below shows the position of these ancient glaciers. They are now gone, but the soil they spread over thousands of square miles is still present.

Glacial soil, like river soil, when not too coarse, is very rich. Like rivers, glaciers mix up the rock material they carry. They dump millions of tons of good rich loam on ground which before they came was covered by lean sand or clay. Farmers, from Maine to Washington and in southern Canada, make millions of extra dollars every year because their farm lands were once buried deep in ice.

When these ancient glaciers melted, they dropped billions of tons of soil on North America



Wind Carries Soil. Fine rock material is continually being picked up and dropped by the wind. In some places wind-blown dust has been piled up on the land to make a soil which is known as *loess*. In China deposits of this sort have been heaped up to more than a thousand feet in thickness over thousands of square miles of country (see the picture on page 280).



Three Lions

These strange mountains in China are made of dust

Loess soils, when not too clayey, are very rich. Some of the best farm lands in Iowa, Germany, and elsewhere have soils made of wind-blown dust.

Exercise. Explore your neighborhood for residual and transported soils. All soils which contain well-rounded grains or pebbles of rock have probably been transported from some other place. Try to determine whether water, ice, or wind brought these soils to their present locations.

WHY GOOD SOIL IS GOOD

Good Soil. We have now gone far enough with our studies on soil to know in a general way what good soil is. We know that good soil must be neither too coarse nor too fine, and that it must contain proper amounts of water, air, humus, and soluble mineral matter. But why must it contain these things, and what are the proper amounts?

Good Soil Contains Enough Water. Do you remember that we learned on page 89 that plants give off water? A healthy plant is like a pipe through which water is always flowing from the ground to the air. The soil is the reservoir that feeds the pipe. If the reservoir fails, the water stops flowing in the pipe and the mineral foods dissolved in the water no longer reach the plant. It dies—just as we should die if the blood stopped flowing in our blood vessels.

Good soil must therefore contain enough moisture to provide a constant circulation of water through the plants that live in it.

Good Soil Contains Enough Air. Too much water in the soil is as bad for growing things as too little. Plants can die from drowning as well as from thirst. If all the open spaces between the particles of soil are filled with water, plants will suffocate. Some of these openings must contain air. The air in soil is necessary for the plants, and it helps keep certain useful bacteria alive. These, in turn, help produce some of the mineral foods which the plants must have.

Stirring up (*cultivating*) the soil of farm or garden makes it easier for the soil to absorb the proper amount of moisture. It also adds the necessary air. *If soil is well cultivated and well drained, it will always contain enough air.* Worms, beetles, and other animals that live in the soil are valuable assistants to the farmer and the gardener because they help cultivate the soil.

Exercise. How to show what earthworms do to the soil: Place several earthworms in the bottom of a glass jar, as shown on page 282. Add three or four inches of loose

These boys are studying the effect of earthworms on the soil

black earth. Cover the earth with about the same amount of white sand or sawdust. Scatter a little corn meal on the surface and soak the mixture with about a quarter of a cup of water. Set the jar in a paper bag to keep it dark so that the worms will work near the glass. Moisten the mixture a little each day. Take daily observations on what happens to the white sand or sawdust. This will show you clearly how earthworms cultivate the soil.

Good Soil Contains Enough Humus. Decaying plant and animal materials, which are known as humus, perform two valuable services for the farmer. They help the soil hold moisture, and they help feed the bacteria, which in turn help produce the crops. When a farmer plows under the stubble of last year's corn and when he covers his fields with manure, he is adding humus to the soil.

All growing things need humus. A few plants need soil which is almost entirely humus. Most plants, however, need much less than this. Too much humus makes soil sour with acids. "Sour" soils are generally good for flowers but bad for most farm crops. Like water, humus can kill if used too generously.

Good Soil Contains Enough Soluble Mineral Matter. Plants live on mineral matter. Unless soil contains this matter in soluble form so that the plants can take it in with the water, it is not good soil. All plants need the elements sulfur, iron, and magnesium. These, fortunately, are present in proper quantities in practically all soils.

All plants likewise need the elements calcium, phosphorus, potassium, and nitrogen. These, unfortunately, are not always present in soil in sufficient quantities. Even if they are present in sufficient quantities at first, the growing plants tend to use up the supply.

To meet this serious problem the farmer can plant different crops on a given piece of land from year to year, because different plants have different mineral requirements. Wheat, for example, needs a great deal of nitrogen from the soil. Clover, on the other hand, needs no nitrogen from the soil. It has the peculiar ability of taking this element from the air with the help of the bacteria which cling to its roots. In fact, it *gives* nitrogen to the soil. So by planting a field first to wheat and then to clover, the nitrogen in the soil is not exhausted. Changing crops in this fashion to preserve the supply of mineral foods in soil is known as *crop rotation.*

The use of fertilizers is another means of helping plants obtain the proper kinds and amounts of mineral food. Soil that is poor in any of the necessary minerals can be enriched through the use of the proper fertilizer. *A fertilizer is any material that contains soluble mineral matter which plants can use.* Even where crops are rotated, some fertilizers are necessary.

THE CONSERVATION OF SOIL

The Problem of Saving America. The conservation of soil is part of a problem so great that it may almost be called the Problem of Saving America. For America is really in grave danger. She is in danger of being destroyed—not by a foreign enemy but by her own people.

In Chapter VI we saw something of this problem in the damage which has been done to the waters of America by widespread abuse of the surface of the land. The same kind of abuse has affected the soils of America. Soil is being carried off to the sea at an alarming rate because of the folly and greed of certain citizens. And the process by which it is carried off is so violent that it ranks as a major national calamity.

The Menace of Floods. Though people are just waking up to the fact that our soils are disappearing, they have long been aware of the menace of floods. As recently as the winter of 1937, the mighty Ohio River repeated an age-old disaster. The picture on the opposite page shows what happened to Cincinnati at that time. Multiply this scene by the hundreds of miles over which the flood extended and you will have some idea of the hundreds of thousands of homeless people, the hundreds of millions of dollars of property damage—to say nothing of the many dead from drowning and exposure—which this single flood brought about. And floods of more or less serious nature are practically a yearly occurrence somewhere in this country.

Pictures, Inc.

Rivers in flood are our enemies

The Wrong Kind of Flood Control. What has man done to protect himself against this terrible foe? The photograph on page 286 almost entirely answers this question. It shows a *levee* built along a river to keep the water from spreading when the river rises. Nearly two thousand miles of such levees have been built at tremendous expense along the lower Mississippi alone. Deepening and straightening the channels of rivers by dredging has also been done at least partly in the interest of flood control, but the levee is the chief defense against floods on most of the rivers of this country.

The illustration on page 287 shows what a weak defense the levee often is. Though levees are likely to hold during minor floods, they are terribly unreliable during great floods. *Levees, indeed, tend to increase the danger of floods.*

Galloway

Levees hold rivers in their channels—except when the levees break

During low-water stages rivers tend to build up their bottoms by depositing sand and mud between the levees. The result is that the levees must be built ever and ever higher. In some places in Louisiana this process has gone on until the river is actually flowing *above the level* of the houses in the valley.

Think of the tragedy that might come if such a levee ever broke! It would probably be far greater than if the levee had never been built. The water would be likely to rush over the surrounding country before many could escape to higher ground. And levees do break in spite of all that man can do to strengthen them. They have been an endless expense; yet the worst floods in the history of this country occur along the lower Mississippi, where levees are most abundant.

The unhappy truth is that levees do not stop floods, because they attack the wrong end of the problem. The way to stop floods is not through levees on the lower parts of rivers but through conservation measures on the upper parts.

Exercise. Look up the story of the Mississippi flood of 1927. How much protection did levees give at that time?

The Right Kind of Flood Control. The water that floods the lower end of a large river enters for the most part through hundreds of little streams at the upper end of the river. The map on page 289 shows the pattern of the great Mississippi River. Notice how it spreads like a tree over the vast central portions of the United States. The "twigs" and "branches" are the feeders of the main river, and it is in them that floods are born. The same thing is true of all other rivers regardless of size.

en a levee breaks, the flood is worse than it would have been if the levee had never existed

Pictures, Inc.

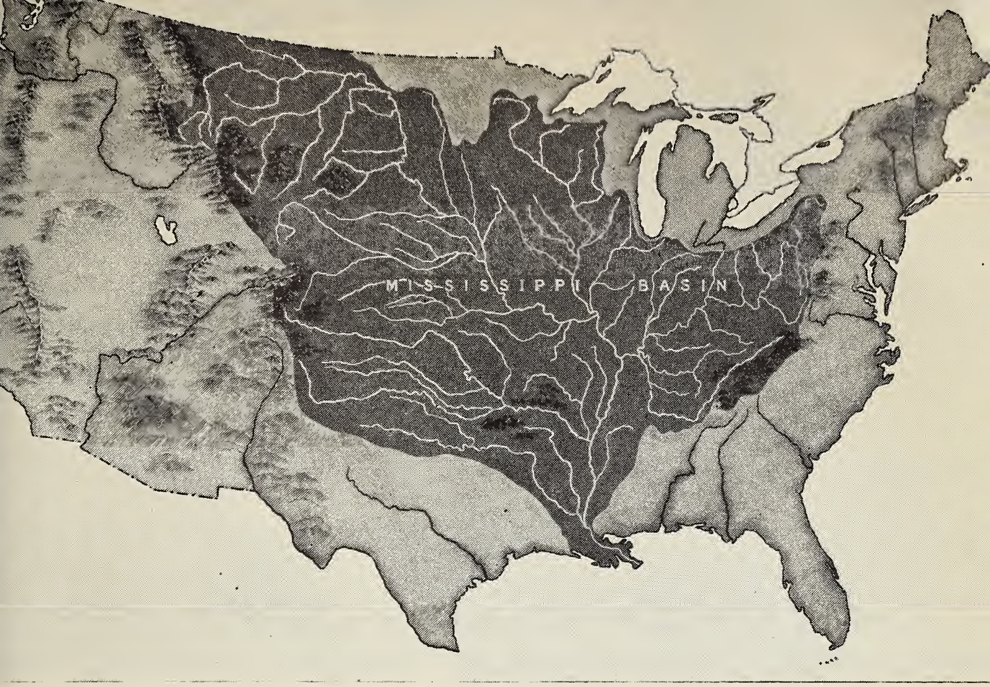
The reason that floods are practically a yearly occurrence in America is that the natural protection of the headwaters of our rivers has been widely destroyed. Too many axes have laid low too many trees. Too many sheep have cropped the grasses too short; too many plows have opened great wounds in the skin of the earth. The result of all this is that rain water falling on such butchered regions is no longer slowed down by vegetation in its movement to the sea. Water rushes into the feeder streams of rivers and thence in torrents to the main rivers. The swirling waters rise in their mad rush to lower ground. The rivers break through their channels and spread disaster far and wide.

The answer to this problem is clear. Forests and grasslands must be restored along the feeder streams of our rivers. Grazing and plowing must be limited or banished wherever they make it possible for rain water to flow over steep slopes unchecked by vegetation. Lumbering, farming, and stock raising must become less stupidly selfish—and they must become so at once.

Exercise. Write to your senator for literature describing the flood-control measures which the national government has put into practice in your state. Would you say that these measures were the right or the wrong kind of flood control?

Our Soils Must Be Saved. Floods, though terrible in themselves, are only part of a broader, more serious problem. For ages men have thought of the soil as a possession which they could never lose. They are just now waking up to the fact that they have been wrong. They now know that *soil as a whole and not merely its soluble minerals can be destroyed.*

Soil, as we have learned, is largely rock material which



The Mississippi River is a tree whose fruit is floods

is resting in its journey from the highlands to the sea. If anything disturbs it in its resting, it takes up its travels again. Men are just now waking up to the fact that they have been blindly and selfishly speeding the soils of the earth on their way to the sea. In a few thousand years they have helped remove from the farm lands of the earth soils which were tens of thousands of years in getting there.

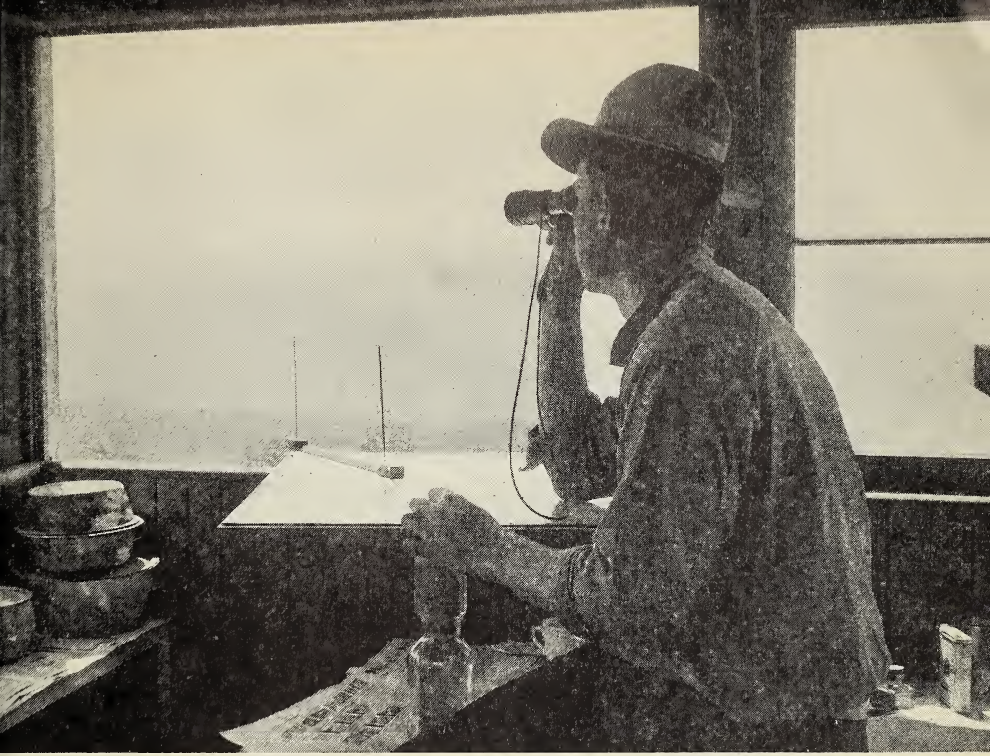
The roots of trees and grasses are the brakes which nature uses to slow down the movement of soil no less than water. By cutting down the trees at the heads of rivers, and by overplowing and overgrazing the grasses along their banks, men have laid open the soil to the merciless attacks of rain, running water, and wind. The result is not only death-dealing floods, but death to the rich topsoil of countless farms.

Men are only now waking up to the fact that *the soils* *of the earth are vanishing more rapidly through the activity of water and wind than they are being replaced through the breakdown of solid rock.* The thick, rich ancient soils of China are measurably thinner and poorer now than they were a thousand years ago. The same is true to a lesser extent of the less ancient farm lands of America. Men are now waking up to the unhappy fact that they have been helping to destroy one of their most valuable possessions.

How Our Soils May Be Saved. Fortunately it is not too late to check the destruction of our soils. Good methods are known for achieving this end, and the government has led the way in educating the people in their use. Just as crop rotation (which we studied earlier in this chapter) preserves the soluble mineral matter in the soil, these new methods preserve the soil as a whole. Let us see what these methods are.

In the first place there is *forest conservation.* The destruction of forests, particularly around the headwaters of streams, must be stopped. New trees must be planted on cut-over and burnt-over forest areas so that their roots and matting of dead leaves will soak up the rain and slow down its rush to the sea. The pictures on the opposite page show how forest conservation is practiced in many state and national forests.

Closely related to forest conservation is *grassland conservation.* Grazing areas must be carefully regulated so that the grasses are not killed and the soil given over to water and wind. The drier parts of the Western Plains must be freed both from the plow and the teeth and hoofs of grazing stock. The terrible dust storms of these regions can be stopped only by letting grass come back to regions from which it should never have been removed.

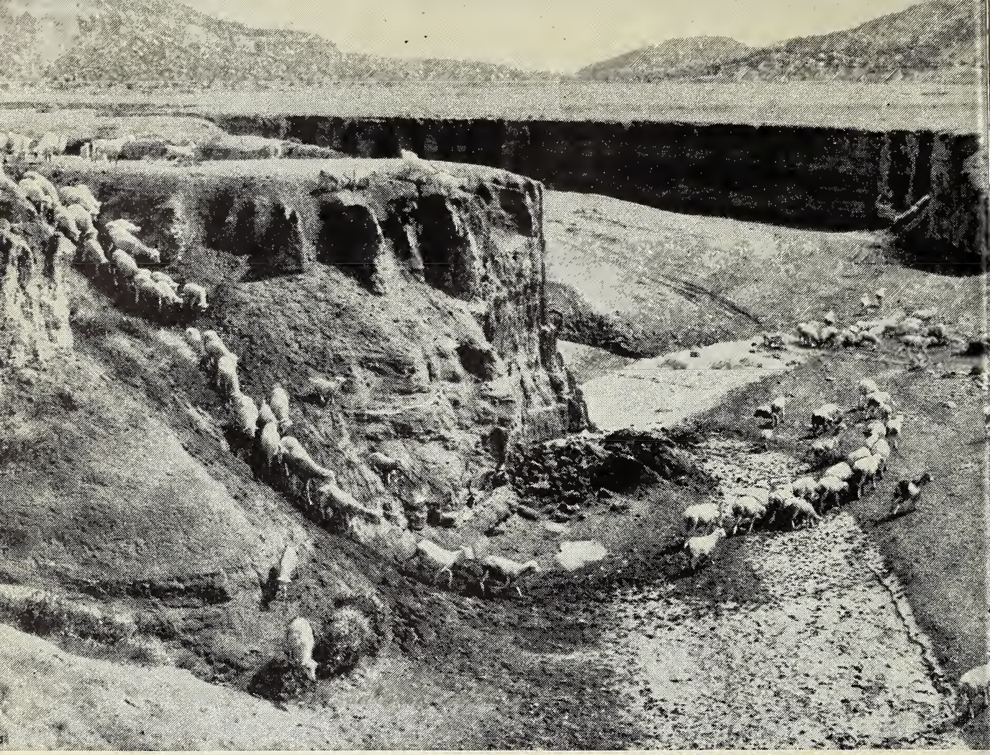


U. S. Forest Service

On many a lonely mountaintop the forest lookout watches for smoke

many a forest nursery young trees are grown for healing the wounds made by fire and the ax

U. S. Forest Service



U. S. D. A., Soil Conservation Service

Too many sheep are making it possible for water to destroy this land

When the grass dies, the dust storm is born

Galloway

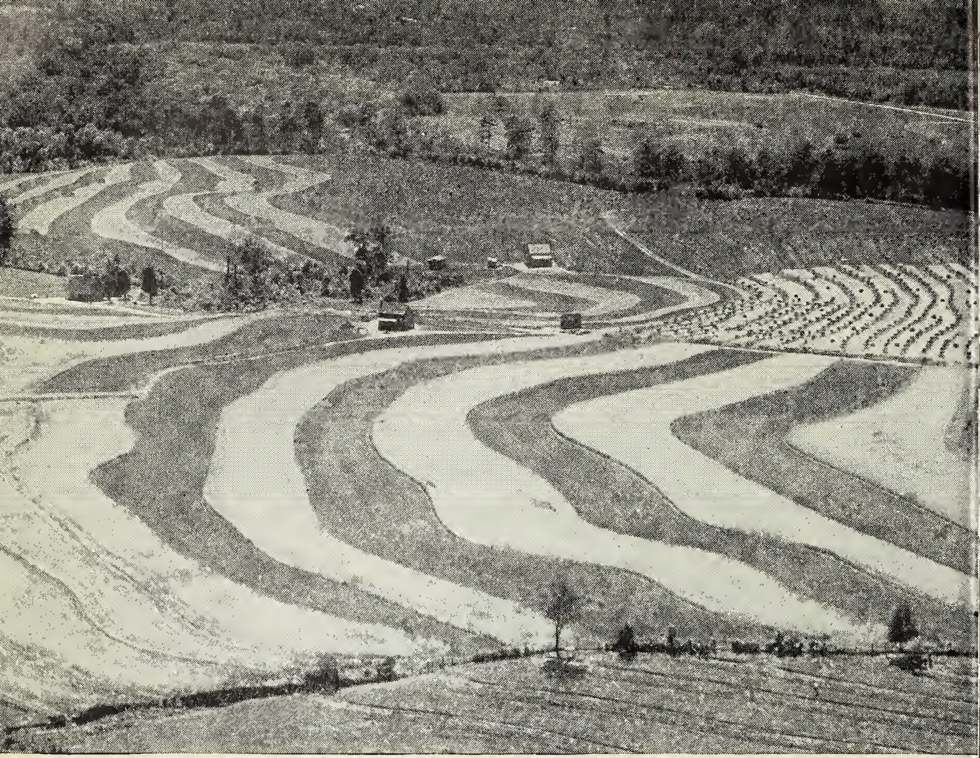
Plowed-field conservation is no less important than forest and grassland conservation. Steep slopes should be allowed to take on their natural covering of wild vegetation. Gentle slopes should not be plowed in the usual square patches but in furrows that curve round the slopes, as shown on page 294. Each furrow thus acts as a little dam to break the rush of rain water downhill. Each trough between two furrows acts as a sponge to soak up the rain which might otherwise escape, taking valuable soil along with it.

There are many other forms of soil conservation, but these are the main ones. If they are put into practice all over the country, the beauty and bounty of our country can yet be saved.

Exercise. Make a survey of the country around your home town or city and see (1) where soil has been washed from the farm lands by rain or blown away by wind; (2) where soil-conservation methods have been put into practice; (3) where such methods could be and should be put into practice.

The Meeting Place of Worlds. We have now come to the end of our explorations in the world of rock. In our mind's eye we have followed the rocks in their slow but mighty changes from form to form. We have paid particular attention to the soil because for us it is much the most important part of the world of rock. Our lives no less than the lives of plants are rooted in the soil.

Our interests as students of the world in which we live can also find valuable food in the soil. The soil is the meeting place of all the worlds of which our world is made. Water, air, rock, living creatures, and action all unite to produce the wonderful drama of the soil.



U. S. D. A., Soil Conservation Service

This is the proper way of farming in hilly country. Notice how the plowed and plan
areas curve round the slopes, thus acting as dams to check the flow of rain wa

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. In a world of constant change the hills alone are eternal.

2. Modern science has proved that the ancient philosophers were right in their belief that limestone caverns were scooped out by the wind.

3. One of the most beautiful sights in limestone caverns is the stalagmites which hang from their ceilings.

4. Trees growing in the cracks of solid rocks protect the rocks from enemies which would otherwise break them to pieces.

5. Glaciers have always been restricted to mountain-tops and have therefore not affected the rocks over any considerable percentage of the lands.

6. Soil is rock which is broken into such fine particles that it is impossible to tell what minerals it contains.

7. Humus is only rarely present in soil.

8. It is impossible to have too much water in soil which is used for gardening or farming.

9. Sandy soil is never good for farming because it is too coarse to hold water.

10. Clayey soil is the best soil because it is the richest in water and mineral plant foods.

11. Residual soils are generally richer than transported soils because their soluble minerals have not been washed away.

12. Earthworms in soil are bad for growing things because their tunneling lets in too much air.

13. The farmer never has to worry about the nitrogen and phosphorus in the soil, because there is an inexhaustible supply of these elements in all soils.

14. Thanks to the levee, we no longer have to fear floods in this country.

15. Good soil is one possession that we can never lose.

Questions for Discussion

1. Usually better crops are raised in valleys than on mountain sides. How many reasons can you find for this fact?

2. In New England you can find great boulders on the tops of hills. How do you think they got there?

3. What sort of soil would you expect to find near the mouth of the Mississippi?

4. Should the national government direct the important work of saving our soils from water and wind? If you believe that the national government should not direct this work, how do you believe our soils can be saved?

Things to Do

1. Get samples of two or three distinctly different kinds of soil. Plant a few seedlings of corn or beans in each soil, but use the same kind of seedlings in all the soils. Give the growing plants equal amounts of sunlight and water. After three weeks write a report on the kind of soil which seems best for the plant, and give reasons for your conclusion.

2. Prepare a poster to show with pictures how soil is formed. If possible, take photographs in your own neighborhood to illustrate soil formation.

3. Place a healthy potted plant in a bucket of water so that the pot is just covered with water. Observe it daily for a week or two. What happens? Why?

4. Start a "Soil Library" for your classroom. Write to the Superintendent of Documents, Washington, D. C., for a list of free publications on soil. *Rich Land, Poor Land*, a book by Stuart Chase, will be helpful in connection with this project.

5. Read Paul B. Sears's *Deserts on the March*. This book will show you vividly how wind and water are destroying more valuable soils than they are producing.

UNIT FIVE

THE WORLD OF LIVING CREATURES

EXPLORING THE WORLD OF LIVING CREATURES

As we have studied the worlds of water, air, and rock we have here and there caught glimpses of another world.

This world is easily the most fascinating world of all.

It is also the world of which we ourselves are perhaps the most important part,—the world of living creatures.

◆

Each day unnumbered creatures, including ourselves, are engaged in the business of living.

Though each day we live and see others live, do we know exactly what living is?

◆

How do creatures compete and how do they co-operate in the business of their lives?

How are they fitted for what they do?

What are the relationships of other creatures to men?

◆

These are mighty questions which the wise men of many ages have tried to answer.

Shall we follow in the footsteps of the wise men and see what we can learn?

CHAPTER TWELVE

What Is the Business of Living?

WHAT ALL LIVING CREATURES DO

Where Creatures Live. In exploring the worlds of water, air, and rock we had frequent glimpses into the lives of plants and animals. Do you remember the strange white mice of the New Mexico desert? Do you remember the host of creatures, both large and small, which we found in the world of water? Do you remember that we even found bacteria and yeast living on the dust in the air, and lichens on cold granite boulders?

We have already seen enough to know that plants and animals do not live only in the pleasant places of the earth. If we climbed to the rocky summit of a mountain, we might well find eagles and rock rabbits living there. If we traveled to the frozen waste lands of northern Siberia, we should certainly find mosses and reindeer living there. Even the water of hot springs is the home of simple plants. *Plants and animals have swarmed over all the earth.* If our eyes are sharp, we can find them anywhere we may go.

The Living World Is Complex. The creatures that live in the worlds of water, air, and rock are themselves a world. The living world, indeed, is much the most complex of all the worlds. Scientists have been studying it for centuries, but they do not yet know how many different kinds of plants and animals exist. Each year, in fact, they discover interesting new kinds of creatures, as well as interesting new things about creatures they have known for a long time.

Where can we begin our explorations in this vast and complex world? How can we travel in it without becoming confused and hopelessly lost? How can we answer the question What is life?

Many people have already tried to answer that last question. Their answers have been much like the answers which the blind men of a famous old story gave to the question "What is an elephant?" One blind man grabbed the elephant's trunk and said, "An elephant is like a rope because he is long and thin and limber." Another blind man, who had hold of a leg, said, "Oh, no, you are absolutely wrong. An elephant is big and round and tall like a tree." A third blind man, sitting on the elephant's back, said, "Why, you are both most certainly wrong. An elephant is broad and flat like the ground." Each blind man was certain that he knew exactly what an elephant was.

In trying to answer the question What is life? we are all likely to be like the blind men of this story. Since we are able to see but a relatively small part of life, we are likely to mistake that part for the whole. Nobody in the world is wise enough to know exactly what life is. You will not be wise enough to know when you have finished studying this chapter. But *by trying to find out, you can learn a great deal about the business of living.*

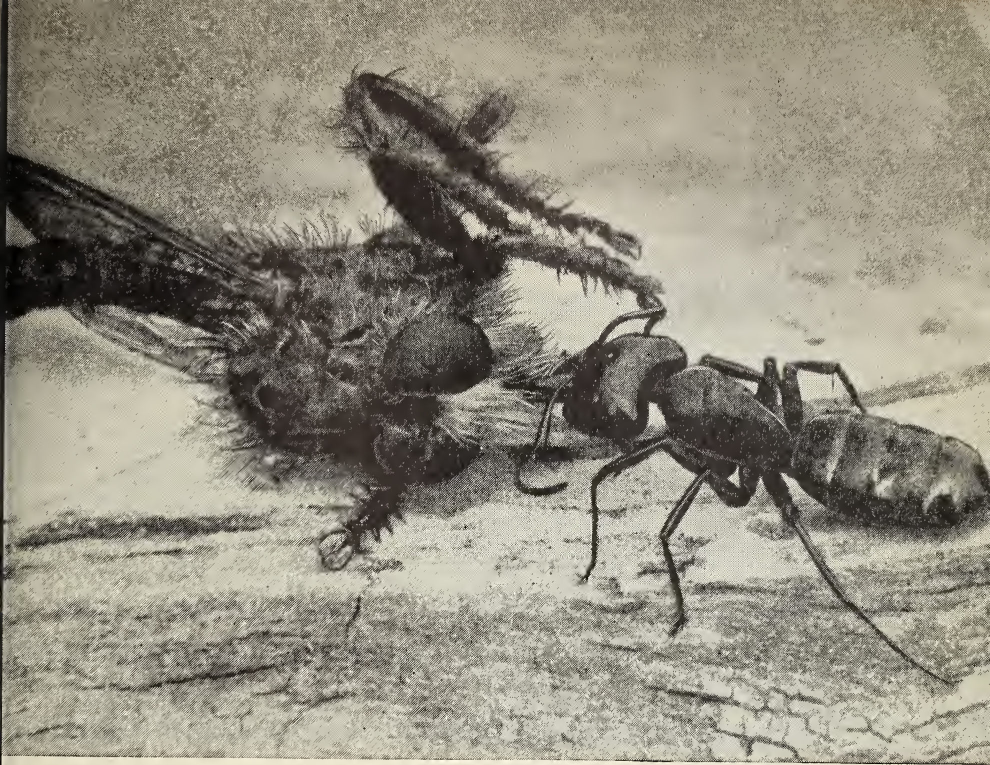
Nobody can see "life." We can only see living creatures. And what vast and varied hordes of them there are wherever we go! In our dooryard there are ants and beetles and perhaps a fat old toad beneath the hedge. There are birds in the air almost wherever we go, and fishes in the water. In the woods and meadows around the town there are squirrels and mice, mosquitoes, hornets, and butterflies, perhaps a few deer and hedgehogs. Trees and flowers and grasses are everywhere.

All these creatures are going about their business. If we could only learn what this business is, we should perhaps have a start toward knowing what life is. But where in a world of so many different creatures can we find any two whose business is the same? In our study of soil we tried to discover the general nature of soil before we searched for the differences between particular kinds of soils. But where can we look for similarities between things so different from one another as cabbages and cows?

All Living Creatures Must Eat. The problem is not so difficult as it first might seem. We do not have to be very good observers to see that most animals are busy workers. If we watch an ant or a robin or a squirrel, we can easily see how busy our animal neighbors are. We can also easily see that for the most part they are busy getting food. The ant is laboriously carrying a seed to his hill. The robin is energetically snapping up worms on the lawn. The squirrel is busily storing nuts in a hollow tree in preparation for the coming winter.

Whatever animal we choose to observe, we can see that much of its time is devoted to the business of eating. The same is true of whatever plant we choose to observe. Though most plants do not move around actively in their search, they are continually seeking with their roots and leaves for the mineral foods which keep them alive. We may therefore conclude that *eating is an important part of the business of living*. No matter how different living creatures may be in habits and appearance, they are yet alike because they all must eat or die.

Exercise. Study the feeding habits of some kind of animal that is common in your neighborhood. Answer the fol-



Lynwood Chace

gging this dead wasp home is a big job for the ant, but there will be a big feast when the job is finished

lowing questions: 1. Does the animal live largely on plants or on other animals? 2. Does it live largely on one kind of food, or does it have a mixed diet? Describe the kinds of food it eats. 3. How many minutes in an hour does it devote to eating? 4. Do you think that in a day's time it would eat more or less than its own weight?

You may be surprised by the results of your observation. Most animals are tremendous eaters. Ordinary caterpillars and hummingbirds, for example, may eat several times their own weight every day!

All Living Creatures Must Protect Themselves. It is easy to see that eating requires being eaten. A worm, for example, eats the tiny plants and animals that live in the humus of soil. A toad may eat the worm, a snake the toad, and a pig the snake. Then you may come along and eat the pig. Do you see how the need for food ties living creatures together? The chain that leads from the worm to you is called a *food chain*. All living creatures are links in one food chain or another.

Exercise. Think of the observations which you have made in the past on the habits of living creatures. Make a list of food chains or parts of food chains you can remember having seen.

You might well ask that if creatures are devoted to devouring one another, why did they not all disappear long ages ago? The answer is that nature has protected her children against their need to eat. She has protected them in two ways.

First, more creatures of every kind are born than can be eaten by their enemies. Foxes, for example, eat rabbits, but many more rabbits than foxes will be born in any given region. In this way the foxes can eat all the rabbits they need without killing off all the rabbits. Though *individual* rabbits must die, the *tribe* of rabbits can go on living. The tribe of foxes can go on living too, because with always more than enough rabbits to eat, it cannot disappear through starvation. And what is true of rabbits and foxes is also true of many other creatures.

Hummingbirds are built for drinking nectar from this kind of cup

A. M. N. H.

Second, all creatures have ways of protecting themselves against the attacks of their enemies. The cactus, for example, has sharp prickers, or spines, that keep off the hungry animals of the desert. The mud turtle can draw his head and feet into his shell. The clam and the mole can hide from their enemies in burrows. The jellyfish can sting its enemies; the shark can bite them; the tiger can claw them; the spider and snake can poison them; the deer and the antelope can run away.

We may conclude from this that *self-protection is just as important as eating in the business of living.* No matter how different living creatures may be, they are yet alike because they all must protect themselves or die.

Exercise. Make a list of all the ways you can think of by which living creatures protect themselves from their enemies. See which member of the class can produce the longest list.

All Living Creatures Must Reproduce. Every individual plant and animal must someday die. Some adult insects live only a day and some trees live five thousand years, but sooner or later they both must pass away. It is easy to see that if nothing happened to replace those which had died, all creatures would long ago have disappeared from the face of the earth. Our planet would long ago have become as empty as the moon.

Rabbits are able to stay on earth because they are much more numerous than their enemies

Lynwood Chace

Courtesy Dr. Raymond J. Pool

All living creatures must protect themselves. An animal would have to be pretty hungry to be tempted by this spiny citizen of the dese

The process of reproduction meets this problem. The pair of robins that raised their young in your maple tree last spring may both die before another spring comes round. Some of the young robins, however, will probably still be alive to take the place of their parents. In this way the tribe of robins goes on living though individual robins die.

"Reproduction" means "to produce again," and refers to the business of having young. Every kind of creature must reproduce if it is to continue being represented in the living world. Some kinds of plants reproduce by developing seeds which grow into new plants of the same kinds. Some kinds of simple creatures reproduce by merely dividing in two. Some kinds of animals, such as birds, lay eggs which hatch into new birds of the same kinds. Some kinds of animals, such as cows, do not lay eggs. Their young are born alive and closely resemble their parents from the start.

We may conclude from this that *reproduction is just as important as eating and self-protection in the business of living.* No matter how different living creatures may be, they are yet alike because they all must reproduce if their kinds are to remain on earth.

Exercise. Make a list of the plants and animals which you have observed at the business of raising their young. In each case explain, if possible, how the young are protected through the dangerous period of early life.

How All Living Creatures Are Alike. Do you see how we have now arrived at an important general conclusion about the living world? We have discovered that *life for all the different kinds of creatures on earth consists in eating, self-protection, and reproduction.* No matter how differently different plants and animals do these things, they all must do them or disappear.

THE LIFE OF A TREE

Perhaps there are some woods near your home. Let us go there and observe creatures that are actually engaged in this business of living. A wood is a place where many creatures live. It is particularly the home of trees. Let us, then, study first the life of a tree.

The Parts of a Tree. Though there may be several different kinds of trees in the woods, they are all built according to the same general pattern. They all have *roots* by which they are anchored to the ground. They all have *trunks*, which support the *branches*, which in turn support the *leaves*. Why are all trees built according to this same general plan? Before we can answer this question we must study the details of the plan and see what advantages they may have.

The roots of a tree are a large and important part of it

J. Horace McFarland Co.

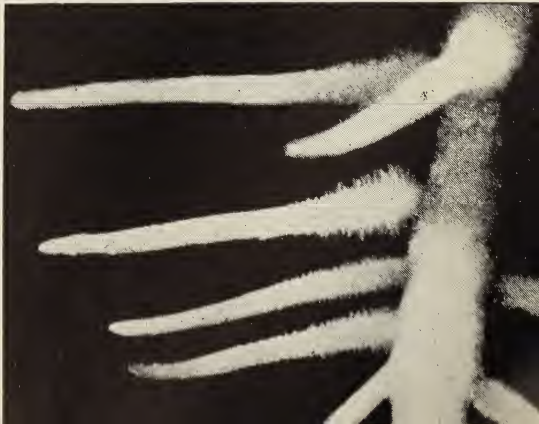
The Roots of a Tree. Trees, like most other forms of plant life, live on the simplest elements and compounds of earth and air. *The business of roots is partly to anchor the tree in the ground but chiefly to obtain water and dissolved mineral material from the soil.*

The illustration on the opposite page shows a tree that is being moved from one place to another. Observe how much of the tree consists of roots. The main roots have smaller branches, which are known as *rootlets.* Several magnified rootlets are shown at the right. Notice that they are covered with a fuzzy growth of many tiny fibers, the *root hairs.* Each rootlet has thousands of such root hairs. It is these that suck the water and mineral salts from the soil.

Exercise. Study a piece of root. If you cannot conveniently get a piece of tree root, a radish, a beet, or a garden weed will do. Wash the soil from the root very carefully and see if you can discover any root hairs. Make a drawing of your specimen, showing the relationship of root, rootlet, and root hairs.

A large oak tree may need as much as eight hundred pounds of water on a summer day! Such a tree must have millions of root hairs and they must all keep very busy to satisfy this need.

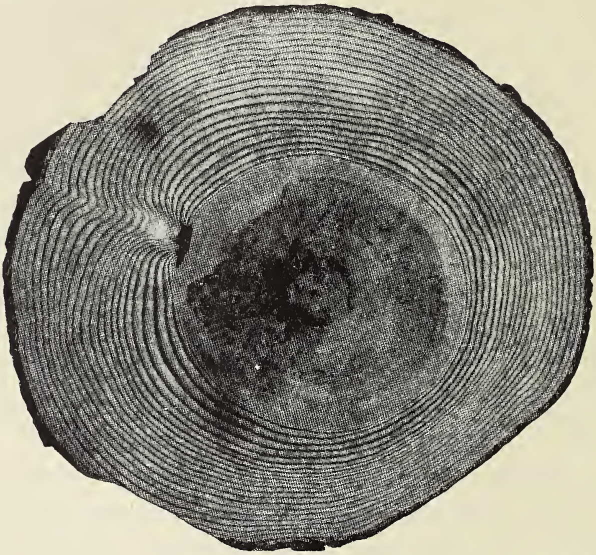
The Trunk of a Tree. *The business of the trunk, or stem, of a tree is partly to carry water and mineral matter to the leaves and partly to raise the leaves into the sunlight.* It also carries the sugar (which, as we shall see, is



The tiny hairs on these magnified rootlets take water and mineral matter from the soil

Erpi Classroom Films

manufactured in the leaves) downward to all the living parts of the tree.



U. S. Forest Service

Can you find the bark, the cambium, the sapwood, and the heartwood on this section of a tree trunk?

The picture above shows a tree trunk which has been sawed through so that you can see what is inside. Notice that the trunk is made of layers of wood. The outer rough layer is called the *bark*. The dark circle just inside the bark represents the *cambium*, or growing region of the trunk. Layers which become bark grow on the outside of the cambium, and layers that become wood grow on the inside of it. The layers between the cambium and the center of the trunk are divided into the lighter layers of *sapwood* and the darker layers of *heartwood*.

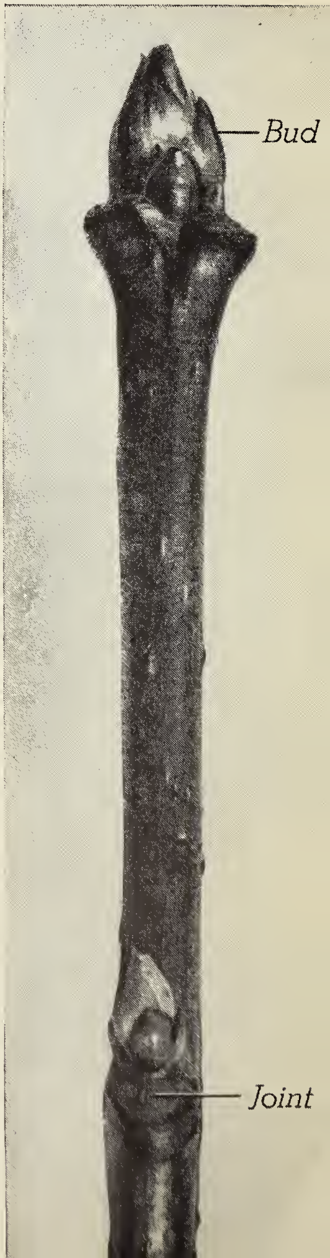
As a tree grows its trunk gets larger. Each year a layer of wood is added to the inner wall of the cambium. The layers of wood die soon after they are formed. When a tree is cut down we can determine its age simply by counting these layers, or rings, on the stump.

Exercise. The tree shown on the opposite page suffered an injury which made the layers on the left wavy. How long before the tree was cut down did this happen?

Only the Outer Rings of a Tree Trunk Are Alive. In the outer rings of sapwood the wood consists of little tubes through which water and mineral matter pass from the roots below to the branches and leaves above. The outer rings also act as warehouses where food manufactured in the leaves is stored. The inner rings around the heart of the tree (the heartwood) are dead. They merely act as a column to support the branches and leaves.

Exercise. Try to find a freshly cut stump of a tree. Count the rings and determine the age. Make a drawing of the cut surface, labeling bark, cambium, sapwood, and heartwood.

The Branches of a Tree. If you examine a growing twig or branch of a tree in autumn, you will find that the tip consists of a bud. After the bud opens in the following spring and performs the duties which we shall describe in a later section, the twig or branch grows rapidly in length. By autumn the new portion of the twig or branch grows a new bud at its end. Over and over this



Rutherford Platt

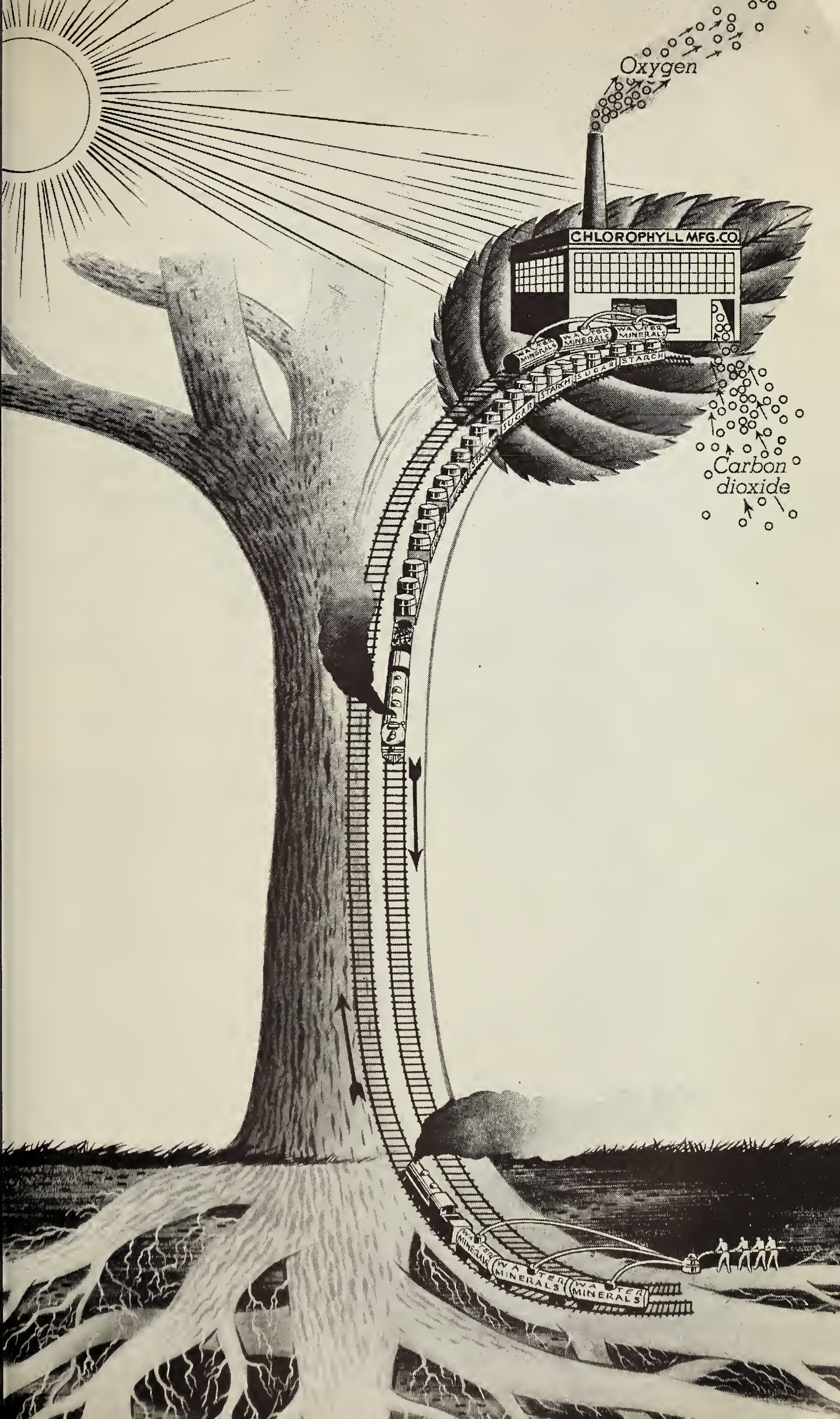
The distance between the joint and the bud at the tip is the amount this twig grew in a year process is repeated with the years. Old branches and twigs grow longer and new branches and twigs are added.

The illustration on page 311 shows a typical twig of a tree. Notice the bud at the end. Notice the kneelike joint which marks the position of an old bud, and the smoother section between the joint and the bud at the tip. *Each section between the joints of a twig, or between a joint and the bud at the end of a twig, is the growth in length during a single year.* After the first year each section grows fatter but not longer. It grows as the trunk grows, by adding yearly layers of wood beneath the bark.

Exercise. Get a branch from a healthy tree. Measure the length of new growth at the ends of the twigs and report your findings to the class. Do the branches of all trees grow at the same rate?

The Leaves of a Tree. The chief purpose of trunk and branches is to support the leaves in the sunlight and to keep them supplied with mineral material and water. *The leaves are factories for the production of food, without which the tree could neither live nor grow.*

The drawing on the opposite page shows how these factories work. Water and mineral matter are piped from the soil through trunk and branches to the leaves. The leaves use this material plus carbon dioxide, which comes from the air, to manufacture sugar. The manufacture of sugar by leaves is one of the most marvelous and mysterious processes in the world. No scientist knows exactly how it is done. Scientists do know, however, that it can only be done with the help of sunlight and the green coloring matter in leaves which is known as *chlorophyll.* "Chlorophyll" comes from two Greek words which mean "green" and "leaf."


Oxygen
CHLOROPHYLL MFG. CO.
WATER MINERALS
WATER MINERALS
WATER MINERALS
STARCH
SUGAR
STARCH
SUGAR
STARCH
Carbon dioxide
WATER MINERALS
WATER MINERALS
WATER MINERALS

Sugar thus produced is added to water brought up from the soil, and the two become sap. Some of this sugary liquid is changed into solid starch by another marvelous and mysterious process. We all know starch in the form of potatoes and other vegetables. All green leafy vegetables and shrubs make starch from sugar, just as all trees do.

Sugar and starch are the chief foods that make it possible for plants to live and to grow. The sugary sap of trees moves from the leaves *down* the inside of the branches and trunk to the roots, thus nourishing every living and growing part. When more sugar is produced than is needed, it is changed into starch and stored in the various parts of the tree for later use.

If trees and other green plants were not able to manufacture sugar and starch, there would be no animals on earth. Animals cannot live without these vegetable foods, and they cannot manufacture them for themselves. They must steal them from the plants.

Exercise. Make a sketch of the underside of a green leaf. Draw in the veins, which act both as rods to support the leaf and as pipes to carry water and soluble mineral matter. Peel the thin skin off the undersurface of the leaf and examine it under a microscope. Notice the little openings through which carbon dioxide enters the leaf from the air.

The Pattern of a Tree. We have now examined the general pattern of a tree. From the tips of the roots to the tips of the branches, a tree is fitted for the job of manufacturing sugar and starch from water and carbon dioxide. All trees are fitted to do this and all trees are built to the same general pattern.

How a Tree Protects Itself. Trees, like all other living creatures, must protect themselves or die. As we walk through the woods near our home we can see that trees are protected in many ways. *The fact that the trees are there at all proves that their method of self-protection is effective.*

We notice that many little trees are struggling for life at the feet of the bigger trees. It is easy to see that there is not enough room for all of them to grow up into big trees. Some of them must die. But because there are more trees than can possibly grow to be full-sized trees, the *tribe* of trees is protected. When an old tree dies, there will always be a young tree ready to take its place. Do you see how this is a most valuable protection for the trees in general, even though it means the sacrifice of many little trees?

e there is not enough room for all of them to grow up,
some of these little pine trees must die

U. S. Forest Service

Exercise. Study the trees in a piece of woodland about the size of a large room. Count the full-grown trees in the area. How far apart do they stand? Next count the very small and the half-grown trees. How far apart do they stand? How many of these will probably die before they take the places of the old trees?

Individual trees, as well as trees in general, have means of protecting themselves. Many different kinds of creatures depend on trees for food. Squirrels and chipmunks depend on them for seeds. Certain birds depend on them for fruit. A great variety of insects eat not only the seeds and fruit of trees but also the leaves and the bark. How does a tree protect itself from these enemies?

Exercise. Observe a tree for an hour and make a list of all the creatures that visit it. Try to determine which creatures, if any, are harming the tree and how the tree protects itself against their attacks. Carefully examine the trunk, branches, and leaves of a tree for damage done by other living creatures. Where is the damage greatest?

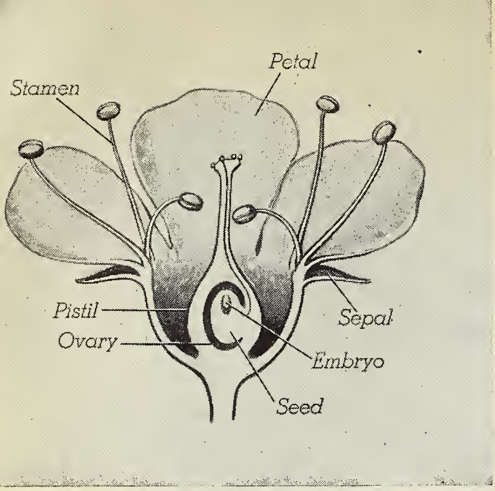
Your observations should show you that not all the creatures that visit a tree are harmful. The birds which nest in a tree and take an occasional meal from it more than pay for what they get by eating the worms and insects that damage the leaves. Your observations should show you that the bark protects most of a tree fairly well. They should show you that *though the leaves are unprotected, there are more than enough of them to manufacture enough food both for the tree and for the worms and insects which the birds fail to catch.*

Individual trees are protected in much the same way that the tribe of trees is protected. Each tree makes more than enough food for its own needs. It can therefore share this food with others. Usually it is only when a "plague" of enemies descends upon a tree that it fails to protect itself. The photograph below shows such a "plague" of grasshoppers. For some poorly understood reason, the enemies of these grasshoppers failed to hold down their numbers. They have gathered in a swarm and are eating everything in their path. Ordinarily, however, the enemies of grasshoppers hold them in check so that they do no special harm to the trees and grasses on which they feed.

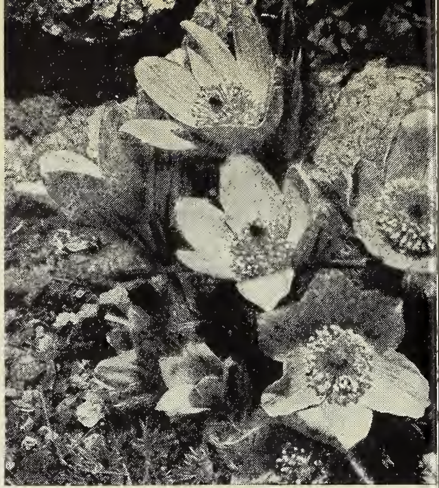
How a Tree Reproduces. In spring some of the buds of a tree may open up into leaves and others into flowers. *Flowers are the reproductive organs of several kinds of trees and of many other plants.* Let us see exactly what a flower is.

This is what happens when grasshoppers are not held in check by their enemies

Acme



This is how a typical flower is constructed


J. Horace McFarland

These anemones display important parts of a flo

The picture at the left above shows the different parts of a typical flower. Observe that the outer covering at the bottom of the flower is made up of green leaflike divisions, the *sepals.* The brighter-colored parts inside the sepals are the *petals.* The *pistil* is a column which rises from the center of the flower's base. The *stamens* are more slender rods which are arranged around the pistil in a circle. Most trees do not have as showy flowers as many of the smaller shrubs and plants.

Exercise. Get a specimen of a living flower and make a drawing of it. Label the parts. Most flowers contain the parts described above; so you may use almost any kind of flower that is handy. If possible, however, choose sweet pea, wild rose, apple, or violet, because these are the easiest flowers to understand.

You will doubtless notice, while drawing a flower, that the ends of the stamens are covered with fine powder. This powder is known as *pollen. Pollen must be carried from stamens to pistil before the flower-bearing plants can reproduce.* The wind most frequently acts as a carrier of pollen. Insects, too, carry pollen from one flower to another in their search for the sugary nectar which many flowers contain. In this way they pay for their dinner by helping the plant that provides it to reproduce.

In examining a flower you will notice that the top of the pistil is sticky. A grain of pollen which is caught on the sticky end of a pistil bores down into the heart (*ovary*) of the pistil. There it unites with material in the pistil and grows into a *seed*. One kind of seed is made of two halves which have a tiny plant (*embryo*) between them. When the seed is carried to the ground and moistened by the rain, the seed cracks open and the embryo takes root. It then grows into a plant which resembles its parent.

Exercises. Obtain an acorn, which is the seed of an oak tree. Remove the outer covering, or husk, and carefully separate the parts, or kernels, inside. Find the little embryo oak tree and make a drawing of it. If you cannot get an acorn, any other kind of large seed will do.

This boy is studying the early stages in the growth of a pea plant

For another experiment, plant some beans or peas in moist sawdust. Watch them sprout. After they have begun to sprout, make drawings of a sprout every other day until you have five drawings. These will show you the early stages in the life of a plant.

THE LIVES OF OTHER CREATURES

The Kingdom of Plants. Now that we have studied the life of a tree in detail, let us look at some of the other creatures of the woods. Beneath the trees are lovely cool ferns and mosses. Violets and other flowers peep shyly from behind the fallen leaves of the woodland floor. Vines cling to the trunks of the trees, and bushes nestle at their feet.

If we sharpen our eyes, we can discover many kinds of plants in the woods besides the trees. Each kind lives its own life in its own way. *Most plants of the woods, however, are alike in being rooted to the ground, in possessing green coloring matter, and in living on carbon dioxide, water, and minerals from the soil.* These three general characteristics are the earmarks of the plant kingdom.

The Kingdom of Animals. In studying trees we observed the squirrels, birds, insects, and other animals that live in and on the trees. Each type of animal, like each type of plant, lives its own life in its own way. Yet the members of the animal kingdom, like the members of the plant kingdom, have certain general traits in common. *Most animals are alike in being free to move from place to place, in not possessing green coloring matter, and in living on solid as well as gaseous and liquid materials.* These three general characteristics are the earmarks of the animal kingdom. Observe that they are almost the exact opposites of the general characteristics of the plant kingdom.

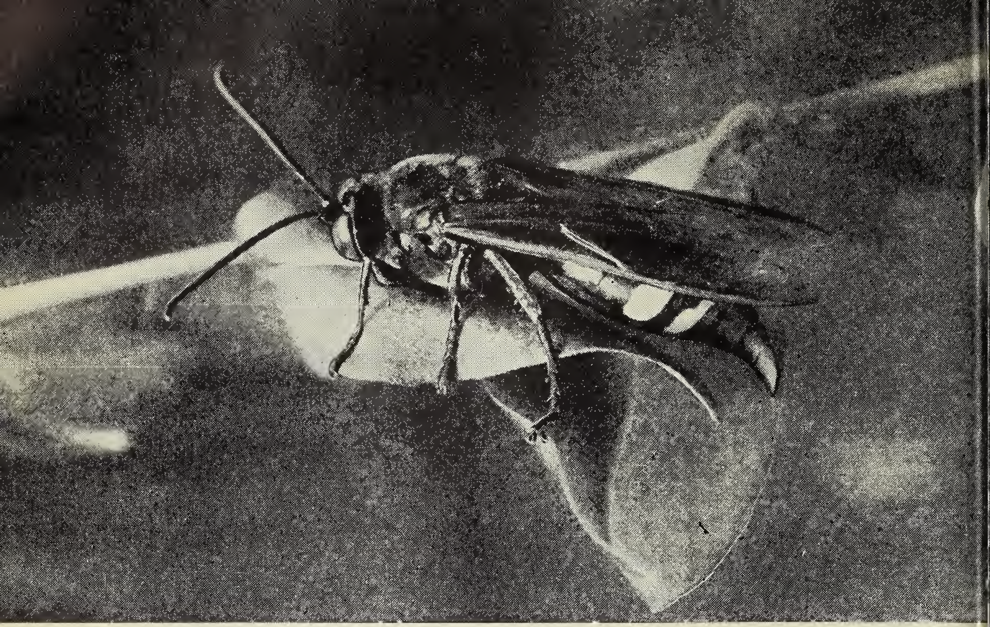
The Differences between Plants and Animals. Plants, which for the most part are rooted to the ground, must manufacture foods from carbon dioxide, water, and minerals. They cannot exhaust the supply of one area and then move on to another.

Animals, on the other hand, can feed over wide territory and on a great variety of food. But they, too, are limited in certain ways. Without green coloring matter they cannot manufacture starch, a food which they must have or die. They must take their starch from the green plants or from other animals. To do this they must have special tools for gathering this solid material and also for digesting it.

Not all animals have the same equipment for eating, because not all animals eat exactly the same kind of food. Some take their starch directly from the leaves and seeds of plants. Some take it from the bodies of other animals after it has been changed into other materials. *All animals, however, must eat solid food of some type*, and must have the proper tools for handling it. They must have such tools as bills for cracking seeds and catching worms or claws for tearing flesh. They must also have such tools as stomachs for churning their food, and intestines for absorbing it.

How Insects Eat. In your walk through the woods you doubtless saw some flies, bugs, butterflies, beetles, or other similar creatures. Such creatures are known as insects. The word "insect" means "cut into." The picture on page 322 shows a wasp, which is a typical insect. Notice how its body is deeply "cut into" in two places, so that it is divided into three parts: the *head* in front, the *thorax* in the middle, and the *abdomen* behind.

Insects are the largest class of animals in the world. Wherever we go we can find them. They are likely to be



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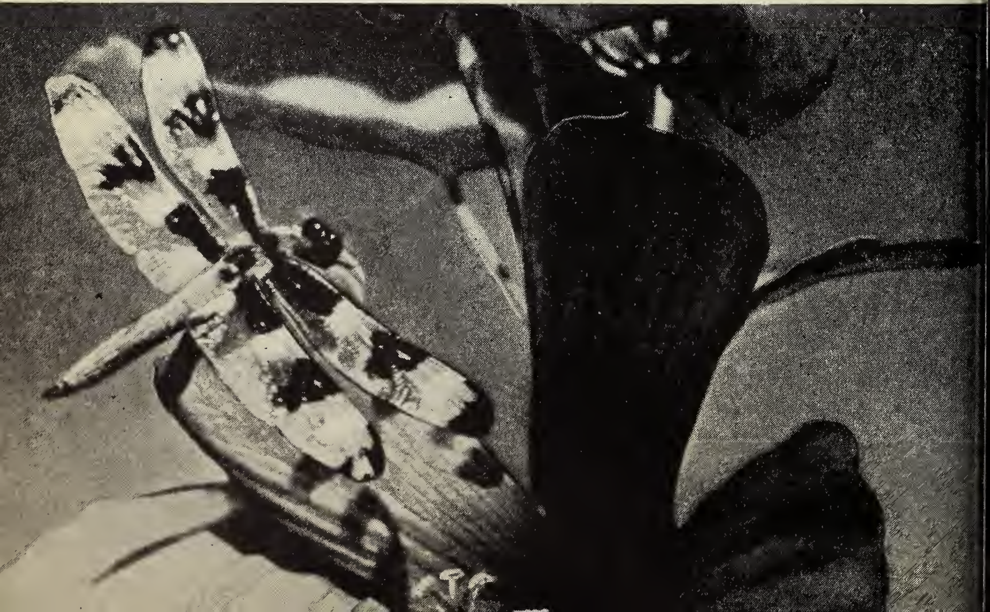
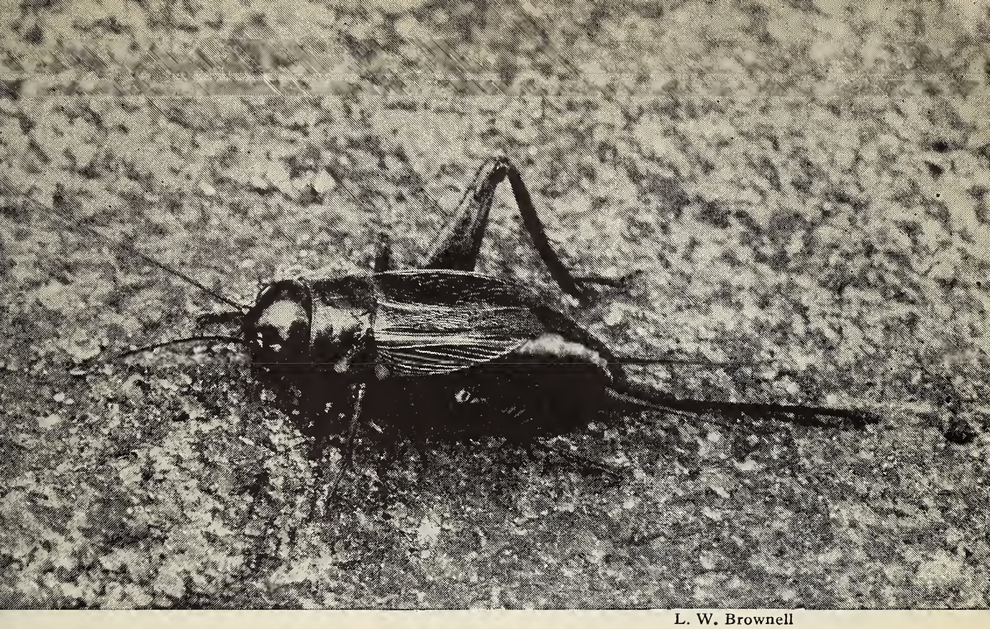
Can you make out the head, thorax, and abdomen of this wasp?

hearty eaters; so it should not be difficult to find some of them at table. Though the table manners of different insects are far from the same, they will show *in general* the way all animals eat.

Large flowers provide good landing fields for the dragonfly, the airplane of the insect world. Nectar of flowers does not interest him because he dines only on me

From *Grassroot Jungles* by Edwin Way Teale





L. W. Brownell

The cricket is a vegetarian

No doubt you can recognize a dragonfly when you see one (see page 322). Dragonflies are meat-eating insects. They live on other insects smaller than themselves, chiefly on flies and mosquitoes.

Like the cricket, the grasshopper lives on plants

L. W. Brownell

Exercise. Study the picture of the dragonfly carefully. Do you think dragonflies catch insects while they are flying or while they are standing still? Why? Do you think they chew their dinner before swallowing it? Why?

The cricket shown on page 323 is unlike the dragonfly in that it prefers plants rather than meat for food. The grasshopper shown on the same page is also a plant-eater. Both these creatures have mouths built for cutting leaves.

Exercises. If possible, catch a cricket or a grasshopper and make a sketch of its mouth parts. If you cannot examine a living specimen, you may find that your science teacher has some preserved specimens which you might study.

Page 325 shows the mouth parts of several different kinds of common animals. How is each animal equipped for eating? Study each sketch and try to determine whether the creature is fitted for plant-eating or for meat-eating. Explain why.

How Insects Protect Themselves. Insects, like all other animals that can move, protect themselves in one of four ways: (1) they may either run or fly from their enemies; (2) they may hide from their enemies; (3) they may depend on their tough shells to ward off the attacks of their enemies; and (4) they may depend on their jaws, claws, or stings to kill their enemies.

Exercise. Describe the methods of self-protection used by as many different kinds of insects as you know through either reading or observation. Describe the methods of self-protection used by five different kinds of animals which are not insects.

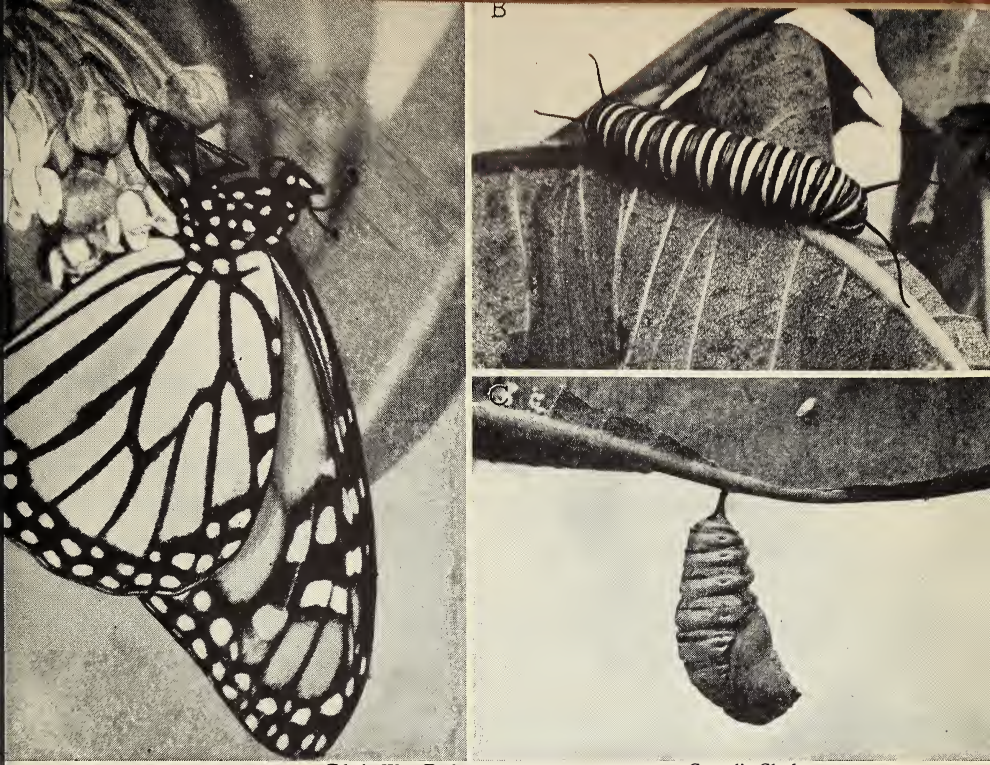
Each individual animal has some means of self-protection, and so has each tribe of animals. One means of protection for animals and plants alike is that there shall always be enough young individuals to take the places of the old individuals as they die.

How Insects Reproduce. On page 327 you may see the portrait of a beautiful brown-and-black butterfly. Have you ever seen this butterfly alive and hovering over the milkweed blossoms in a pasture? It is one of the commonest, as well as one of the largest and handsomest, butterflies in the United States. It is called "the monarch" because it seems like a king among butterflies.

In the same illustration you may see an ugly large green worm. Perhaps you have also seen this creature alive in some pasture. He eats leaves, and his appetite is enormous. Who would believe that this fat and disgusting worm was the child of the monarch butterfly?

The great green worm is truly the child, or *larva*, of the butterfly. In ten days it has grown from a tiny egg the size of a pinhead, which the mother monarch laid. But this is only the beginning of the marvelous story of the reproduction of this butterfly. In a few days more the green worm, or *caterpillar*, will change to the form which is shown at *C* in the picture. This form is known as the *pupa*, or *cocoon*. The pupa is a quiet sac that neither crawls like a caterpillar nor flies like a full-grown butterfly. It will hang as though dead on a fence post or hedge for about two weeks. Then one day the pupa will split open. A monarch butterfly will crawl out and take to the air!

This marvelous method of reproduction is not uncommon among insects. Bees, beetles, ants, mosquitoes, and flies all reproduce through egg, larva, and pupa stages.



Edwin Way Teele Cornelia Clarke

s insect grows from an egg into first a caterpillar (B), then a cocoon (C), and finally the monarch butterfly (A)

Other insects, such as grasshoppers, crickets, katydids, and walking sticks, skip the larva and pupa stages. The young which are hatched from the eggs look very much like their parents from the start.

Most animals grow from eggs just as most plants grow from seeds. For this reason plants and animals are much alike in the way they reproduce, though they are very different in the ways they eat and protect themselves.

Exercise. Study the reproduction of some insect other than the monarch butterfly. Draw pictures of egg, larva, pupa, and adult. The common housefly or mosquito would make easy subjects. If you cannot draw all the stages from actual specimens, draw them from pictures in a book on insects.

Our First Exploration. We have now come to the end of our first exploration in the world of living creatures. We have learned that all creatures, both plants and animals, must eat, protect themselves, and reproduce. By studying trees and insects, we have seen how a typical plant and a typical animal go about these three important parts of the business of living.

We have laid a general foundation for the study of the living world. On this foundation we can add details of particular information about plants and animals as long as we live. And the larger our knowledge about the lives of other creatures grows, the more interesting and happy our own lives are likely to be.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. There are wide areas on the surface of the earth where neither plants nor animals can be found.

2. Most creatures eat very little.

3. Most creatures lead independent lives and have little to do with their neighbors.

4. In any given place, foxes quickly kill all the rabbits that live there because rabbits have no means of protecting themselves.

5. Reproduction is a process by which plants produce more food than they need.

6. The only business of roots is to anchor a plant to the ground.

7. The cambium is the central dead portion of the trunk of a growing tree.

8. The sections between the joints of the branches of trees grow a little in length every year.

9. The sugar which is manufactured in the roots of a tree moves up the trunk in the form of sap.

10. If the pistils of flowers did not produce pollen, all flower-bearing plants would disappear.

11. Birds that eat fruit are the worst enemies of trees.

12. The only real difference between plants and animals is that animals can move around and plants cannot.

13. The larva of a butterfly can neither eat nor move from place to place.

14. Plants and animals are not at all alike in the way they reproduce.

Questions for Discussion

1. Can you properly refer to a growing tree as a factory?

2. Some forms of insect life produce thousands of their own kind each year. Why is it, then, that we are not overrun by insects?

3. Do you see any necessity for us as a nation to be concerned about the protection of wild life? Explain.

Things to Do

1. Place a healthy potted plant in a dark place for some time. Keep it well watered. What do the results of this experiment show?

2. Make a woodland "terrarium" in a glass bowl. A terrarium ("terra" means "earth") is a collection of living land creatures just as an aquarium is a collection of living water creatures. Place clean sand and gravel on the bottom of the bowl and cover this with a layer of loam and decaying

leaves from the woods. Plant ferns, mosses, and small wild flowering plants in this loam. Read *Gardens in Glass*, by Mildred Norton Andrews, which is an excellent book that will give you many practical suggestions.

3. During the late fall and early winter collect the pupae (this is the plural of "pupa") of various moths and butterflies. Bring into the warm science room and await developments. In connection with this work you should look up and read about the life cycles of these insects in *Field Book of Insects*, by F. E. Lutz, or some similar book.

4. Make a study of the plants and animals of your neighborhood. Different groups of students might specialize on such different groups of creatures as (*a*) birds, (*b*) snakes, (*c*) insects, (*d*) flowering plants. Records should be kept of the kinds of plants and animals identified. When possible, specimens should be brought into the science workroom. Any food chains that are observed should be noted.

5. Read Ernest Thompson Seton's *Wild Animals I Have Known* or *Lives of the Hunted*, which tell the stories of wild animals in their struggle for life. Other interesting books are F. M. Chapman's *Travels of Birds* and A. A. Allen's *The Golden Plover and Other Birds.*

CHAPTER THIRTEEN

What Is the Web of Life?

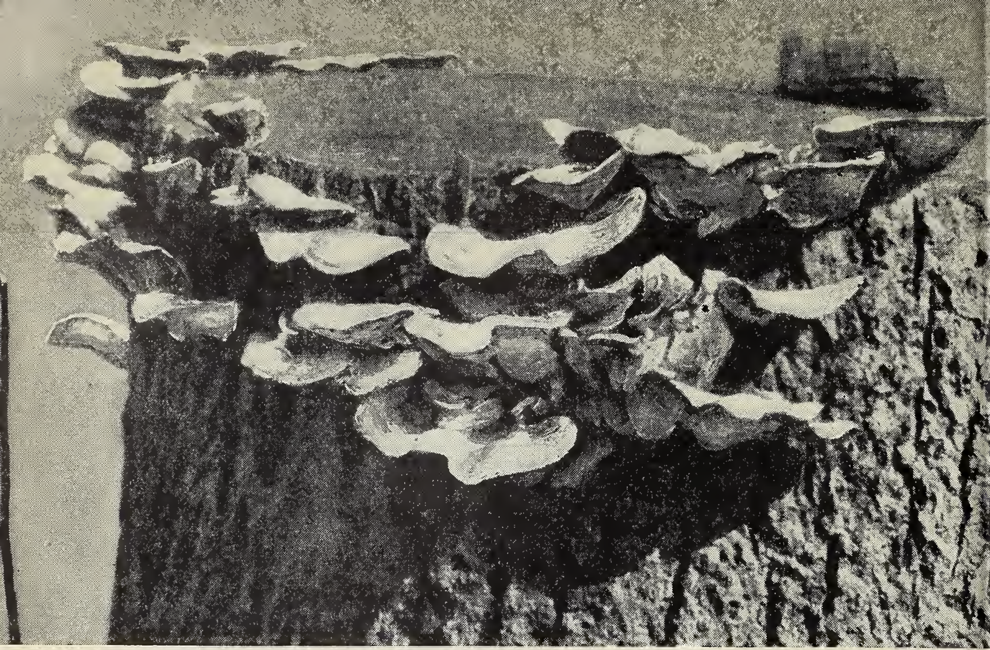
THE WEB OF LIFE IN THE WOODS

How the Living World Is Put Together. In our study of the business of living we had glimpses of how one creature is related to another. We saw how all living things are linked together in food chains. The robins on the lawn, for example, are linked to the worms in the soil because the robins need the worms for their breakfast. The worms, on the other hand, are linked to the tiny plants and animals of the soil for exactly the same reason.

We also saw that living things are related to one another in the business of self-protection. Birds eat some of the fruit of trees, but they repay the trees by also eating the insects which live on the leaves of the trees. In other words, the birds and the trees are partners in the business of living. The birds get food from the partnership, and the trees get protection against their most dangerous enemies.

We also saw that creatures are related to one another in the business of reproduction. The pollen of one flower must form a partnership with material in the pistil of another flower before a new plant can come into the world. Birds, bears, and many other animals form similar partnerships for the purpose of raising their young.

All these and many similar facts prove that the parts of the living world are knitted together more tightly than are the parts of any other world. *No creature can possibly live by or for itself alone.* Eating, self-protection, and re-



Bracket fungi eat the rotting wood of dead trees

production are processes which unite one creature to another. So thoroughly are the lives of plants and animals bound together that poets and scientists have compared the living world to the web of a giant spider.

In the last chapter we caught glimpses of threads in this web of life. In this chapter we shall examine the web more closely.

When a Tree Dies. Let us return to the woods where we studied a living tree. Let us now study a dead tree. In life, as we have already discovered, a tree is related to birds, squirrels, insects, and other creatures. What happens to these relationships when the tree dies? Do they disappear? Do dead trees drop out of the web of life like threads of spider web that we brush away with our hands? Let us see.

Exercise. Examine a dead and rotting log. Do you find any living plants or animals in or on the log? If so, how many can you name? Does a tree's relationships with other creatures disappear when the tree dies?

This simple observation will show you that the web of life has been spun out of dead as well as living creatures. The dead trees of the woods are nurseries for new life,—life which could not exist if trees did not die.

The Nursery of a Rotting Tree. The illustration on the opposite page shows a rotting tree stump with strange mushroom-like growths clinging to its decaying bark. These growths belong to one of the largest groups of plants on earth, the *fungi* (singular, *fungus*). This name comes from a Greek word which means "sponge," and refers to the soft, spongy nature of these plants. The fungi in the picture are called *bracket fungi* because they stick out like brackets from the dead logs and stumps on which they grow. Mushrooms and toadstools are other common members of this great group of simple plants.

Fungi are different from most other plants because they cannot make food for themselves. They have no green leaves to manufacture sugar from water and carbon dioxide. They must take their food, like animals, from other creatures. Rotting wood is one of the favorite foods of many different fungi.

Exercise. Get a piece of rotting wood with a bracket fungus attached. Make a sketch of the specimen and then carefully remove the bark to see how the fungus is attached.

Do you remember our experiment with molds on page 208? Molds are members of the fungi group of plants. If you look carefully, you will doubtless find some of them in the nursery of a rotting tree. Bacteria, too, are there in great numbers, though they are invisible to the naked eye.

The forest floor is the home of many creatures

You may know that they are there because *it is largely the bacteria that make dead wood decay.*

Animals as well as plants are busy in the nursery of a rotting tree. Ants, beetles, and termites live on the wood that has been softened by the bacteria. In the moist soil beneath a rotting log many worms and grubs grow fat on the materials of decay.

The Nursery beneath the Dead Leaves. Beneath the carpet of dead leaves that spreads over the floor of the woods you may find another nursery of living creatures. The dark moist region just below the dry top layers of leaves is a favorite home for bacteria and other simple plants that live on dead materials.

Some animals, particularly earthworms, live on decayed leaves and other forms of rotting vegetation. The earthworm eats soil and humus. As this material passes through its body, tiny particles of plant and animal food are digested and absorbed by the animal's blood. Careful study has shown that in one acre of land as much as eighteen tons of soil may pass through the bodies of earthworms in a single year.

There are many other forms of animal life on the forest floor. Look at the picture on the opposite page. There are grubs, ants, spiders, and "thousand legs" in great variety. There are lizards, snakes, moles, mice, and chipmunks. The moles eat earthworms and grubs; the ants take their food from many sources; the spiders, "thousand legs," and lizards eat insects; the snakes eat insects, moles, and mice. It is surprising to learn how many animals make their homes in the soil of the forest and take their food either directly or indirectly from it. *Actual counts have shown more than two million animals in the surface layers of one acre of soil.*

Exercise. Go to the woods and count the creatures that live in one square yard of the floor. In looking for specimens, sift the top dry leaves and dig a few inches in the dark wet earth beneath them. How many individual living creatures do you find there? How many different kinds of living creatures do you find?

The Dead and the Living Are Partners. Do you see from these observations how all creatures in the woods are more or less dependent upon one another? All plants and animals are parts of the web of woodland life, the dead ones as well as the living ones.

When a tree dies, it provides both food and shelter for many other creatures. *These creatures cause the tree to decay, which means that they turn it back into the water, carbon dioxide, and mineral matter out of which it was made.* By doing so they not only keep themselves alive, but they make a rich soil in which new trees might grow.

THE WEB OF LIFE IN THE FIELDS

A World of Grass. If you go from the woods to a field or pasture, you will find a very different group of creatures living there. But you will find all of them doing much the same things that the dwellers in the woods were doing. You will find them eating, protecting themselves, and reproducing. You will find them all bound together in a complex web of relationships.

You will find particularly a great abundance and variety of grasses and grasslike plants. The pasture is a world of grass. In each green blade of grass the process of foodmaking is going on, just as it does in the green leaves of trees. Thistles, dandelions, daisies, mustard, burdock, cockleburs, and other weeds are scattered through the grass. Stalks of red and white clover brighten many a field and fill the air with perfume from their flowers. All are busy with the endless task of food-making and with self-protection and reproduction.

Exercise. If possible, visit a field in spring or fall and see how many different kinds of grasses and weeds you can find.

The Partnership of Bacteria and Clover. The roots of the field plants, like those of the forest plants, reach into the soil for water and mineral matter. If you dig into a pasture, you will find that the top layer is a mass of roots. The roots of the grass which hold the sod together are a tangle of little fibers.

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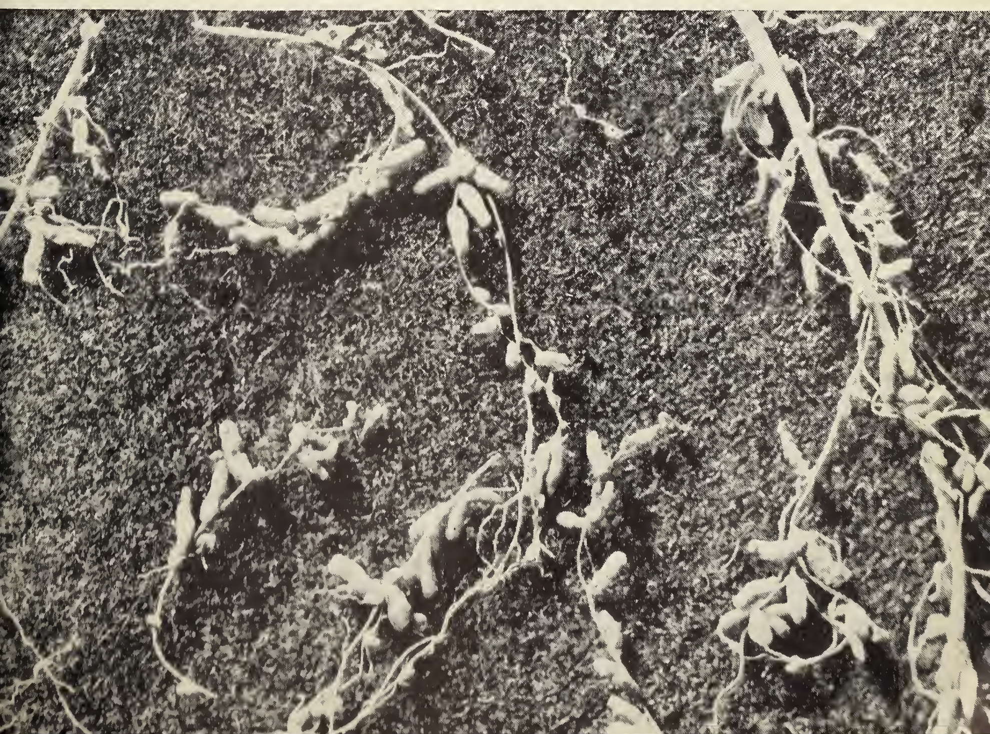
[1] From Pool, *Basic Course in Botany*, published by Ginn and Company.

The nodules on the roots of a clover plant are the homes of millions of bacteria[1]



Clover roots are especially interesting. Study the roots of the clover plant which is shown on page 337. Notice that there are little round bodies attached in bunches to many of the roots. The farmer calls these *nodules*, and he knows that if he grows clover with nodules on its roots he may greatly improve the soil of his fields. A crop such as that illustrated on the opposite page is not grown for its beauty and pleasant odor. Let us see exactly why it is grown.

There is life in the little nodules on the roots of clover, and this life enriches the soil of the field that contains it. *Inside the nodules are millions of bacteria.* These bacteria can take nitrogen from the air. They can combine the nitrogen with other chemical elements and make nitrogen compounds. No one knows exactly how they do it. It is only known that these nitrogen compounds are needed for making *protein*, which, as you will learn in a later chapter, is a valuable and necessary food for all animals. No green plant can take nitrogen from the air without the help of bacteria.

The farmer may plow under his crop of clover so that the plants decay in the soil. In this way the nitrogen compounds are left in the soil. These may be used by the next crop grown in the field. Peas, beans, alfalfa, and some other plants have the same sort of nitrogen-storing nodules. By rotating such plants with plants that do not have the power of storing nitrogen, as we saw in Chapter XI, the farmer can keep his fields supplied with this necessary element.

Do you see how the web of life in the pasture stretches from the invisible bacteria on the roots of clover in many different directions? It reaches to such food plants as corn, which may use some of the nitrogen that the clover has given to the soil. It reaches to the cow that eats the clover and then builds the nitrogen compounds into its flesh. It

J. Horace McFarland Co.

over enriches the soil by giving it nitrogen compounds which are built from the nitrogen in the air

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reaches to us who eat the corn and drink the cow's milk. From these foods we receive the nitrogen which the clover took from the air.

The Partnership of the Clover and the Bee. In the pasture, as in the forest, there is a great deal of insect life. Upon the clover blossoms bees are forever busily seeking food. A bee lights on one blossom, stops a minute, then flies to another blossom. He works over the second blossom for a minute and again passes on. The bee is gathering nectar. Inside his body the nectar is partly digested and changed into honey. The honey is stored and serves as food for the bee during winter, when there are no flowers.

The sugary nectar seems to serve no other purpose for the plant than to attract the bee. You know from your study

L. W. Brownell

The bee pays for the nectar and pollen it takes by helping the plant to reproduce

of the last chapter that the bee is also gathering pollen. Most of what he gathers is taken to the beehive and stored for food. Have you ever seen beebread? This is really stored pollen.

Because the pollen is sticky, some of it clings to the body of the bee. As he travels from one flower to another, some of the pollen from one flower rubs off on the next one. In this way pollen is carried from flower to flower, and the bee helps the clover to reproduce.

Exercise. Make a diagram of a bee on a clover blossom, showing how the bee is able to gather pollen and carry it from flower to flower.

Do you see from the study of clover how the web of pasture life is woven out of many different creatures?

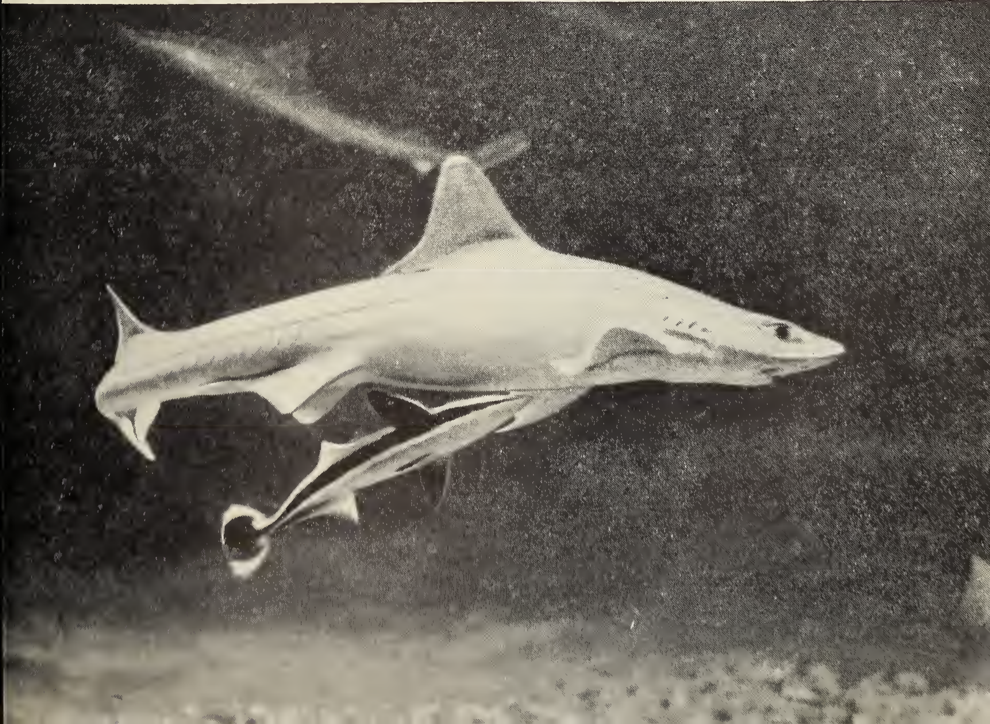
Through the bacteria on its roots and the bees in its flowers, clover is able to live. Many other creatures, both plants and animals, are also able to live. Should all clover disappear from the fields of the earth, many creatures whose lives are tied up with the clover would suffer severely.

HOW LIVING THINGS CO-OPERATE

How Unlike Creatures Co-operate. In your exploration of the living world you have already seen several examples of how creatures "get along," or co-operate, with their neighbors in the business of living. There are many other examples of co-operation between creatures of the same kind as well as between creatures of different kinds. The photograph below illustrates a famous example of co-operation between two different kinds of fishes. The little pilot fish has a sucker-like organ on the top of its head by

The pilot fish "hitchhikes" through the sea on the belly of a shark

N. Y. Zoological Society



which he can attach himself to the belly of the shark. The shark seems content not only that the pilot fish should "hitchhike" in this fashion, but that he should share the food which the shark is able to capture. It has long been believed that the pilot fish pays for these services by directing, or "piloting," the shark to his meals.

Another example of co-operation between animals of different kind is the partnership of the rhinoceros and the birds that pick the ticks from his hide. The next time you see a movie of wild life in Africa, look for these birds if a rhinoceros appears on the screen. Ticks are little burrowing insects which torment many different kinds of animals. By allowing the birds to dig out the ticks the rhinoceros not only gets relief, but he also has quick warning of approaching enemies from his fluttery companions. The birds, on the other hand, get free meal tickets for as long as they care to limit their diet to ticks.

Exercise. Go to the library and prepare a report for your class on the partnership between the hermit crab and the hydroid; between a green alga and a colorless fungus in a lichen.

Parasites. Unfortunately it often happens that one partner takes advantage of another and becomes a parasite. *A parasite is simply a thief that steals the food of another creature without exposing itself to danger.* The illustration at the left shows a mistletoe on a tree. The mistletoe

The mistletoe is a petty thief that steals water and mineral matter from trees but makes its own sugar and starch

U. S. Forest Service

takes water and mineral matter from the tree without giving anything in return.

Some parasites are much worse thieves than others. The mistletoe is a thief of small importance because it uses its own green leaves to manufacture sugar and starch. A far worse thief is the tapeworm shown below. This disgusting creature lives in the bodies of dogs, pigs, cows, and occasionally in men. It attaches itself to the intestines of its victim by the hooks on its head, and robs him of his food. The tapeworm, however, is punished for its crime. It cannot live anywhere but in the dark and stuffy insides of other animals. It cannot see and it cannot crawl. It can only eat and reproduce.

Exercise. Go to the library and prepare reports for your class on *Trichina*, one of the worst parasites in the living world.

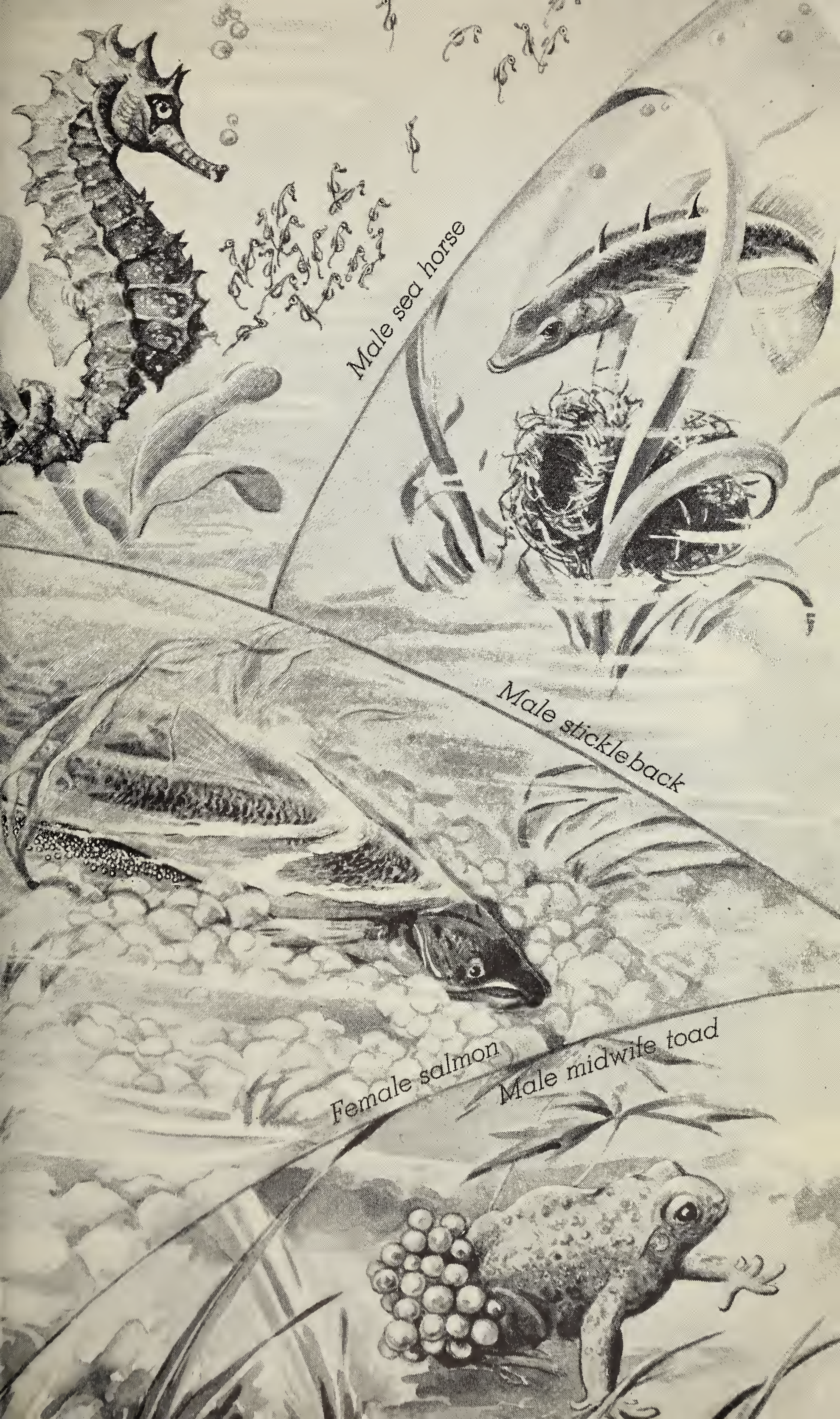
Care of the Young. So far we have studied the relationships between very different kinds of creatures. The most numerous examples of co-operation in the living world are to be found among creatures of the same kind. Such creatures frequently help one another in the business of eating, self-protection, and reproduction.

Perhaps the most intimate partnerships in nature are those which are formed for the purpose of raising and protecting the young. In some cases, however, only the mother animal seems in-

The tapeworm is a thief that steals all the necessities of life from the intestines of its victim

© General Biological Supply House

Robins
Kangaroo
Python


Male sea horse
Male stickleback
Female salmon
Male midwife toad

Wide World from A. J. Klein

Elephants band together in herds for hunting food and fighting off attacking enen

terested in the welfare of the children. In some cases only the father seems to care. In many cases, however, both mother and father co-operate in feeding and protecting their young. Study the illustrations on the preceding pages. It will show you how a variety of animals work for the welfare of their children.

Gregarious Living. There are also many examples of animals of the same kind that flock together for purposes of eating and self-protection. Such animals are said to be *gregarious.* The picture above shows a herd of elephants, a good example of gregarious living. A herd of elephants with its many noses is better able to find rich feeding than is one elephant with his single nose. A herd has more eyes and ears than an individual to discover the enemy lurking in the bush, and more feet and tusks to drive him away. Do you see, then, how gregarious animals benefit by co-operation?

Exercise. List as many different kinds of gregarious animals as you can think of, and in each case tell how you think the animals benefit from their way of life.

Social Living. A few types of animals show far more co-operation than that which we can observe in a school of fish, in a herd of deer, or in any other group of merely gregarious animals. Such animals live in communities, as men do, and are known as *social* animals. Beavers, termites, bees, ants, and certain wasps and beetles have all developed a truly social form of living.

What exactly is social living? We may say that *a group of animals lives socially when it acts as a whole and when*

ers are social animals because they work partly for themselves and partly for their community

F. M. N. H.

the good of the individual is not put ahead of the good of the group. The illustration on page 345 shows what this means in terms of actual living.

Though beavers live in little family groups and have their own private family interests, they also live in communities and have community interests as well. The picture of the beavers shows several of them at work for their community. Notice that some are chewing down trees. Others are ferrying trees over the water. Still others are building the trees into a dam and into an apartment house of sticks and mud beneath the dam, where all the beavers will live in comfort and safety. *All the beavers of the community are at work, not only for their individual good but for the good of the community in general.* They are practicing social living.

Men, who live, like beavers, in communities, do not all do the same kind of work. Carpenters build houses, farmers plow fields, plumbers lay pipes, and mechanics fix automobiles. In other words, the labor that must be done in a community of men is divided so that those who are best fitted to do a certain type of work will do it. We call this a *division of labor.* It is one of the most outstanding features of social living among animals as well as men.

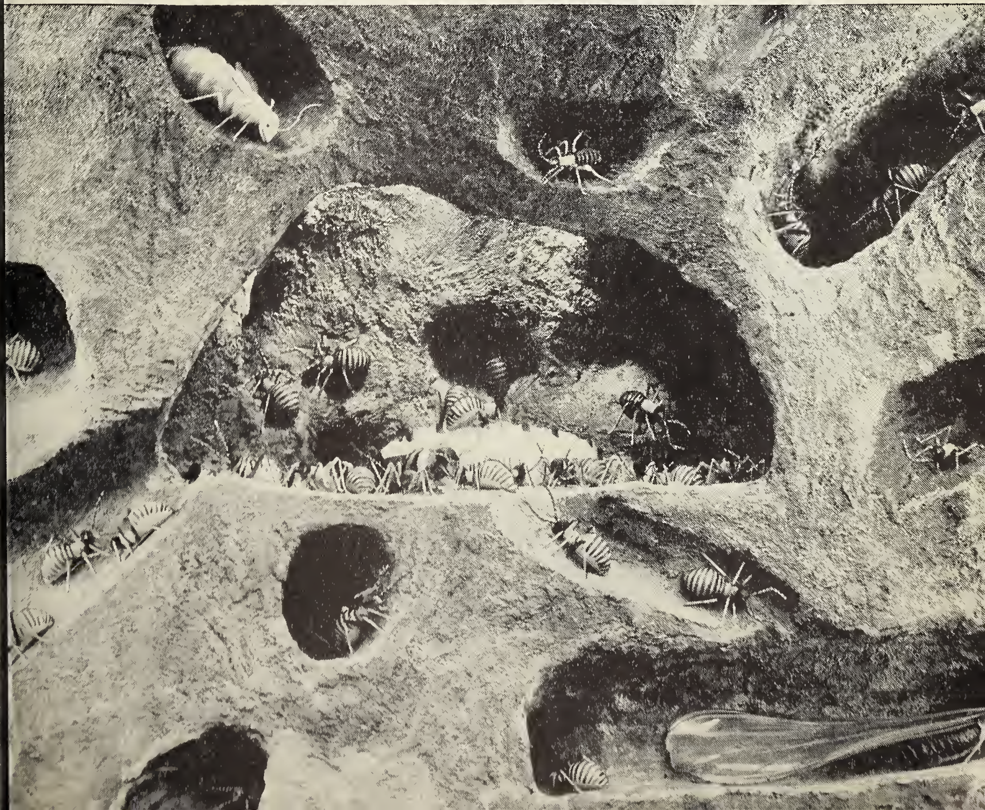
The picture on the opposite page shows how far the division of labor may go among a society of social insects. All the little creatures in this picture belong to the same type of *termite*, or "white ant." They all live in the same community. But they belong to different groups, or *castes.* The castes in a termite society not only do different kinds of work, but, as you can see, the members of the different castes are very different in appearance. There may be as many as eight castes in a termite community, each caste performing some special kind of work.

Exercise. Make a list of all the advantages that you believe might be enjoyed by such social insects as bees, termites, and ants because they live in societies with divisions of labor.

THE BALANCE OF LIFE

Life Is a Play. It would be wrong to conclude from this picture of widespread co-operation in the living world that all creatures are always at peace with one another. We know from what we have already learned about food chains on page 304 that *the web of life is held together by conflict as well as by co-operation.*

Let us for a moment stop thinking of life as a mighty spider web. Let us rather think of it as a mighty play which



this model of a termite colony notice the large white "queen" termite near the center, rrounded by smaller "workers" that feed her and keep her clean. Notice the large nged "king" termite below, and the white "soldier" above with a squirt gun on his head for shooting a sticky fluid at the enemy

Buffalo Museum of Science

is being acted out on the stage of the earth. In this play there are five chief actors.

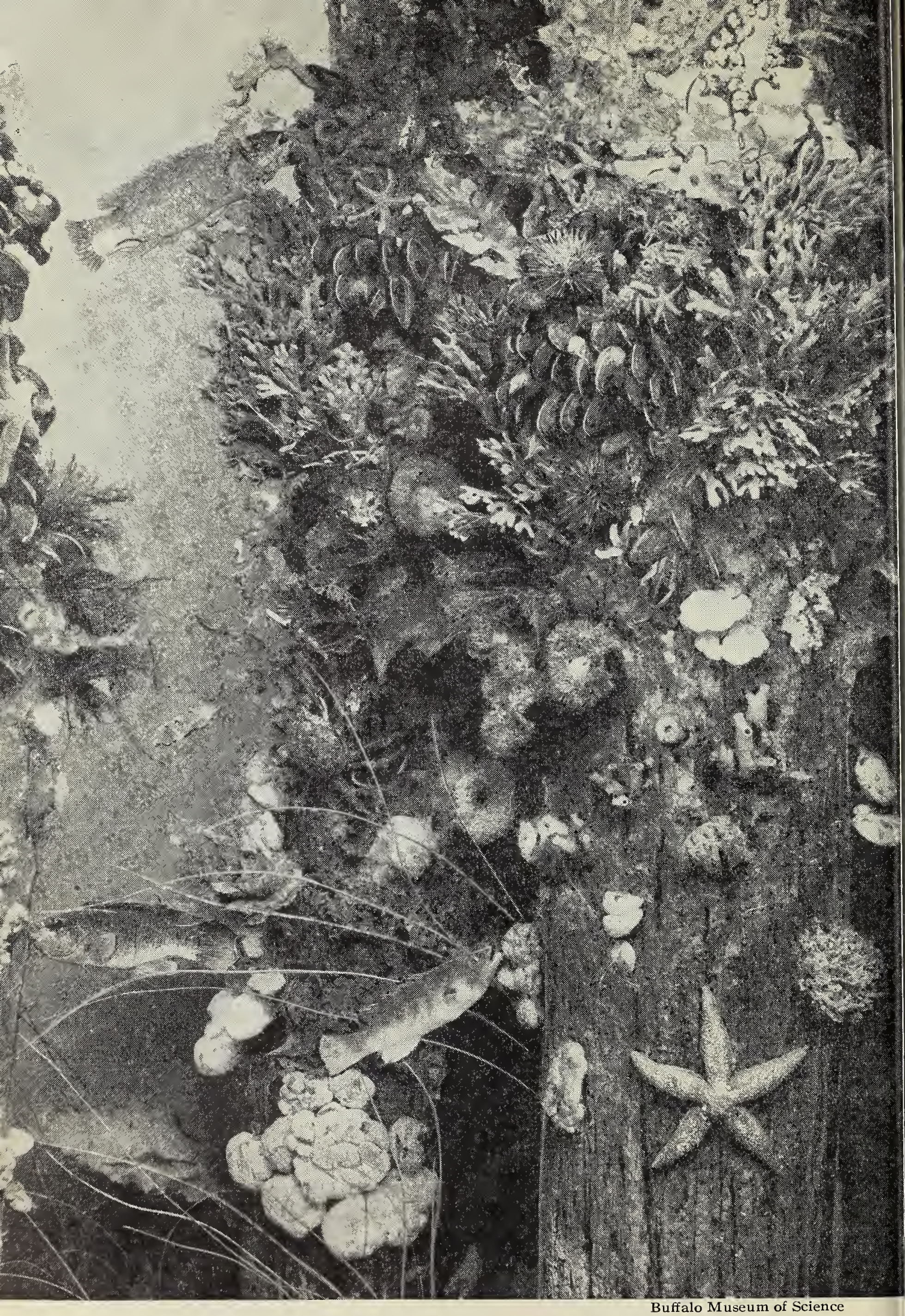
There is *first* the sun, which makes it possible for the green plants to manufacture sugar and starch from water and carbon dioxide. *Second*, there are the green plants, which make food that animals need, but which the animals cannot make for themselves. *Third*, there are the plant-eating, or *herbivorous*, animals, that eat the green plants. *Fourth*, there are the flesh-eating, or *carnivorous*, animals, that eat the herbivorous animals as well as one another. *Fifth*, there are the plants and animals that live on the dead remains of all other creatures.

The Villains of the Play. The carnivorous animals are in a sense the chief villains in the play of life. They are not really villains, for they live their life in the only way they can live it. They are the wolves, tigers, and others that live by tooth and claw. They can exist only by killing their neighbors because they are fitted only for eating flesh.

Exercise. Study the opposite page. Explain how each animal shown there is able to overpower its victims.

Why do not the carnivorous animals in the play of life do away with all the other actors and thus put an end to the show?

The Origin of a Pound of Codfish. To answer this question we must return to a matter which we have already discussed very briefly. On page 304 we learned that more creatures of any given kind are born than can be eaten by their enemies. Let us now examine this truth in greater detail.



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Many different kinds of creatures live balanced lives on this wharf piling at Martha's Vineyard, Massachusetts. Acorn barnacles, periwinkles, black mussels, oysters, seaweeds, crabs, sponges, sea anemones, and starfishes range from the top to the bottom of the structure. How many of these creatures can you identify?

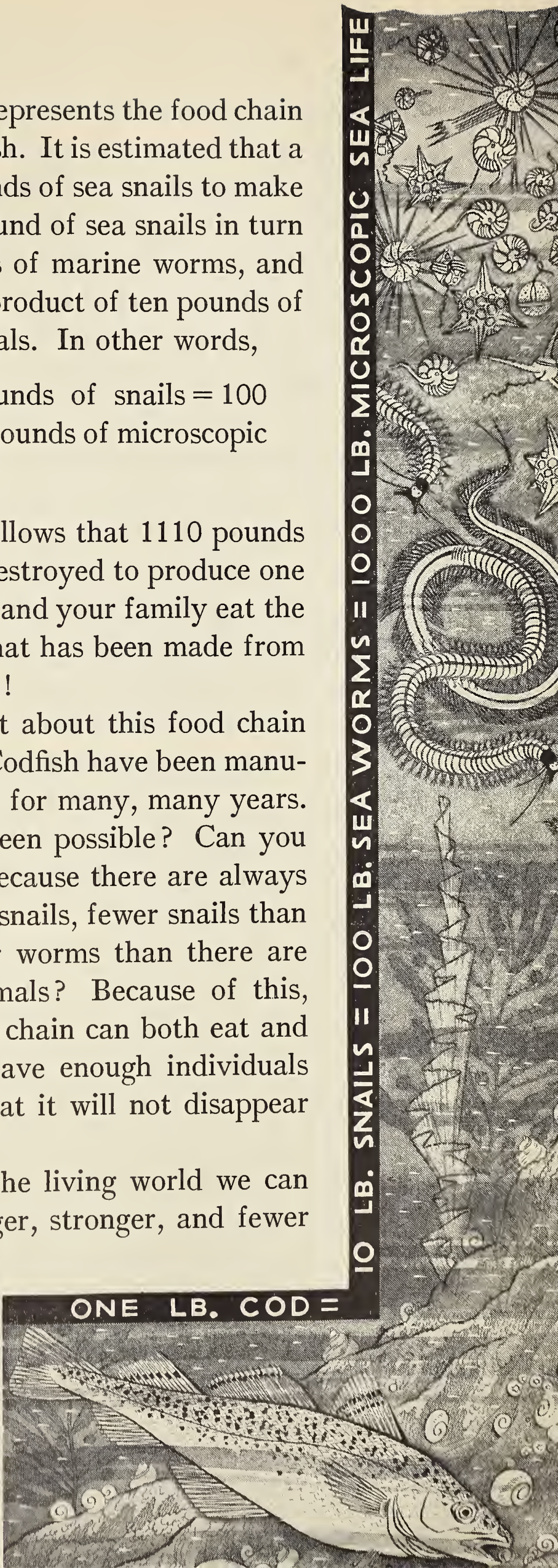
The diagram at the right represents the food chain that leads to a pound of codfish. It is estimated that a cod has to eat about ten pounds of sea snails to make a pound of codfish. Each pound of sea snails in turn is the product of ten pounds of marine worms, and each pound of worms is the product of ten pounds of microscopic plants and animals. In other words,

> 1 pound of cod = 10 pounds of snails = 100 pounds of worms = 1000 pounds of microscopic plants and animals.

By simple arithmetic it follows that 1110 pounds of living creatures must be destroyed to produce one pound of codfish. When you and your family eat the pound of codfish, you eat what has been made from more than half a ton of food!

The most remarkable fact about this food chain is that it does not collapse. Codfish have been manufacturing codfish in this way for many, many years. Can you see why this has been possible? Can you see that it is possible only because there are always fewer codfish than there are snails, fewer snails than there are worms, and fewer worms than there are microscopic plants and animals? Because of this, each kind of creature in the chain can both eat and be eaten. Each kind will have enough individuals left over to reproduce so that it will not disappear from the earth.

Everywhere we look in the living world we can see creatures which are larger, stronger, and fewer living at the expense of those which are smaller, weaker, and more abun-


ONE LB. COD =
10 LB. SNAILS = 100 LB. SEA WORMS = 1000 LB. MICROSCOPIC SEA LIFE

dant. *But because the smaller and weaker creatures are much more numerous than the larger and stronger creatures, both kinds are able to go on living.* In other words, the larger, stronger, and fewer creatures are *balanced* against the smaller, weaker, and more abundant. *We call this the balance of life.*

Do you see now why the villains in the play of life do not stop the show,—why the web of life does not collapse?

When the Balance of Life Is Upset. Because the balance of life is very delicately adjusted, it may be upset for a time in any given place. On page 317 we saw how it is upset from time to time by the appearance of great hordes of grasshoppers on the Western Plains of this country. Something happens to the enemies of grasshoppers so that they become *too few* to hold down their side of the balance. The grasshoppers tip their side of the scales and do much damage in the living world until nature restores the balance. The balance may be restored through a reduction of the number of grasshoppers by disease. It may be restored by the grasshoppers' eating up all the possible food supply and then dying of starvation.

Man has often upset the balance of life. He did this recently by killing many of the coyotes and mountain lions in the Kaibab Forest of Arizona. Thinking that he would thus make life easier for the deer, he really made it much harder. For without their natural enemies, the deer multiplied until there was not enough food in the forest for all of them to eat. They died in large numbers of starvation. Recognizing their mistake, the guardians of the forest allowed hunters to kill some of the deer, and in this way reduced the herd to a size that could live on the food which the forest supplies.

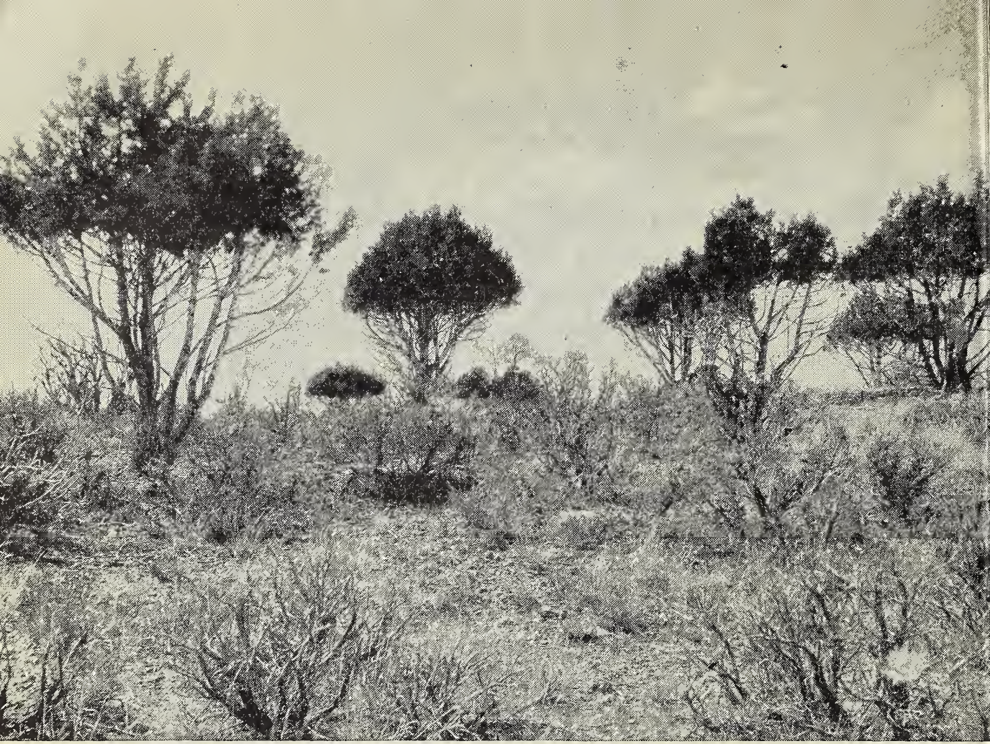
Man has also frequently upset the balance of life by adding to, rather than reducing, the number of creatures that live in a given place. A number of years ago the beautiful elm trees of New England were attacked by a certain kind of worm. The English sparrow was known to eat this kind of worm in England; so he was brought to New England to rid that land of the pest. In fairness it must be said that the English sparrow did what was expected of him. But after he had eaten the worms in New England he multiplied and spread all over the United States, driving the much more attractive native songbirds from cities and villages wherever he went. He upset the balance of bird life throughout the country.

Exercise. Look up the history of rabbits in Australia and mongooses in Jamaica. These are two of the most striking examples of upset in the balance of life.

THE CONSERVATION OF WILD LIFE

The Problem of Conservation. The problem of preserving the balance of life is part of the great problem of conservation. Have you ever gone for a picnic in an unspoiled wood where the birds were singing and a clean little brook sang quietly over the stones? Such places help make our lives worth living. Think of the tragedy of never being able to see a spot of earth that has not been used or abused by man!

More and more, thoughtful people are coming to think of this very thing. Civilization has been an enemy of nature. In Chapter VI we saw how unwise use of the land has seriously harmed the waters of America. In Chapter XI we saw how unwise use of the land has robbed us of valuable soil and given us only death-dealing floods and dust storms in return. In the following paragraphs we shall see how



U. S. Forest Service

When food becomes scarce, deer may eat the leaves of trees up to a level which represents the highest the deer are able to reac

the wild life of America has been sadly reduced by the folly and greed of human beings.

The Problem of Conserving Our Forests. The worst blow that can be dealt to the wild creatures of any region is the destruction of the places where they live and breed. We in America have dealt that blow again and again. It was necessary, of course, as more people came to live in this country, that the wilderness should give way to cities and farms. But we have destroyed more of the wilderness than was needed for the good of our people as a whole, and with it we have greatly reduced the population of game and fish.

There is no darker blot on the record of the United States than the wholesale destruction of the mighty forests which once covered nearly half of the country. The logging industry and its chief assistant, fire, first wrecked the pine forests of the northeast, then the pine forests of the southeast, and then the fir forests of the Far West. Now on the Pacific coast the last of the virgin forests are rapidly falling before these ruthless foes. And with them are falling the animals that live in the forests.

What can be done about this unhappy condition? Trees must be used for lumber as civilization advances; so is not the slaughter of the forests a necessary evil? The answer is that *we can use our forests without destroying them*, through the practice of conservation. We can pass laws which will make it necessary to cut only mature trees. We can replant trees in cut-over and burnt-over areas. We can reduce the waste which has always been a part of logging and milling activities. We can keep the woods clean of "slash" (broken branches and other waste from lumbering) and thus remove one of the strongest invitations to fire.

lumberman has often left behind him not only ruin but a strong invitation to fire to come and spread the ruin further

U. S. Forest Service

Exercise. Look up the work of the Forest Service and report to your class on how this government bureau is helping to save our forests.

The Problem of Conserving Our Wild Grasses and Flowers. In an earlier chapter we saw that overplowing and overgrazing of the natural grasslands of America has turned large areas of once rich land into deserts. We saw that these grasses must be allowed to return by taking the plow and the sheep from the drier regions of the West.

The slaughter of the smaller plants of America has not been confined to the Western Plains. Wild vegetation of every kind has been attacked by the advancing army of civilization. The making of farms and fields has driven many a beautiful wild flower to extinction or to the point of extinction. Fire and drainage of swamps has added to the kill.

There are few people who are willing to lift a hand in defense of our native wild flowers. Those who do not plow up these plants as "weeds" are apt to pick them—too often roots and all—to give a few fleeting hours of decoration to the home. Fortunately, however, some states have passed laws which forbid the picking and uprooting of such native wild plants as are nearing extinction. Private organizations in many towns are also active in this worthy cause. All of us should co-operate to preserve the delicate beauty of the plants that add so much to our picnics and hikes in the fields and woods.

Exercise. If there is a Garden Club in your vicinity, find out what measures, if any, it has taken to preserve the wild flowers of your region. Find out from this organization or from the state what wild plants of your region are in special need of protection.

The Problem of Conserving Our Birds. Birds are among the best friends of man. Without them our farms, orchards, parks, and gardens would be ruined by the millions of harmful insects, mice, and other pests that are waiting to eat any green thing that lifts its leaves to the light. Man must wage ceaseless war against these creatures which threaten to starve him out of the world, and birds are man's ally in the war.

How has man repaid the birds for this priceless service? He has repaid them by slaughtering them. He has killed them in untold millions for food and for fun and to decorate women's hats. In America alone he has completely murdered two whole species of once numerous birds,—the passenger pigeon and the great auk. The trumpeter swan and the California condor he has driven to the very edge of the grave. By cutting down the brush and by draining the ponds and swamps where birds live and breed, he has greatly reduced the numbers of practically all our American species.

This all makes a very sad story, but fortunately it is not the entire story. A great many people love the birds and have done much to protect them. The map on page 358 shows the widespread distribution of government bird and game refuges, where wild creatures can live without fear of guns. Notice the large number of refuges in North

The condor is making a last stand against man in the mountains of California

William L. Finley and H. T. Bohlman

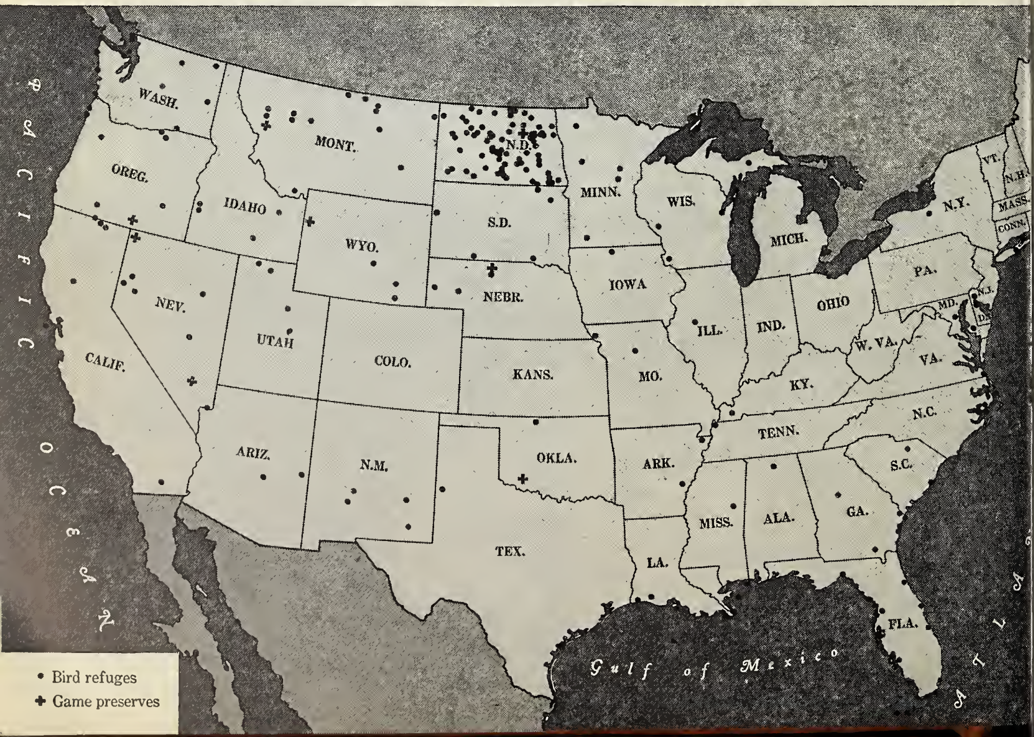
Dakota. These are on swampy lands where wild fowl collect by the millions to breed. Through such measures as these our bird life can be saved.

Exercise. If you are a Boy Scout or a Girl Scout, make a report to your class on what your troop has done to protect the birds of your region. If nothing has been done, make a report on what you think might well be done.

The Problem of Conserving Our Fish and Game. The problem of saving the fish of our waters and the fur-bearing animals of our fields and woods is similar to the problem of saving our birds. We must set aside places where these creatures can live in safety. This means, in the case of fish, that we must stop polluting our waters with sewage and the waste from factories. It means, in the case of our four-footed neighbors, that we must provide a homeland for them which is safe from the plow, the ax, and fire.

Most civilized countries have passed laws which are aimed to conserve the precious wealth of the plant and

Each black spot on this map indicates a haven of safety for wild life



animal kingdoms. In this country we have fish and game laws to regulate hunting and fishing both as sport and business. We have set aside great tracts of land as state and national parks, forests, and monuments where wild creatures can live unmolested by men. We have taken steps to protect these places against their deadliest enemy, fire.

These are noble and sensible acts, and they make up in part for the ruthless destruction of such creatures as the passenger pigeon and the bison. We must remember, however, that *conservation can never go too far* in a world of expanding industry and increasing human population. Each one of us can do his bit toward the conservation of wild life. We can at least plant a tree where one seems to be needed, or feed the birds in winter. We can be careful of fire in the woods.

Our Second Exploration. We have now reached the end of our second exploration in the living world. In our first exploration we discovered that life is a business of eating, self-protection, and reproduction. In this second exploration we discovered that life is a vast web of relationships between creatures that are all trying to eat, to protect themselves, and to reproduce. We discovered that the web is marvelously put together; that all the different creatures in the world are woven into it; that though it may be torn in places, it collapses only when man interferes.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. When a tree dies, its relationships with living creatures disappear.

2. Fungi are green plants that live on dead materials.

3. Bacteria do not get into a dead log until after it begins to rot.

4. Fewer creatures live in the carpet of dead leaves on the floor of the woods than anywhere else in the world.

5. Many bacteria on the roots of clover will kill the plant.

6. All plants give nitrogen to the soil.

7. Bees are parasites on plants because they take nectar without giving anything in return.

8. Gregarious animals have developed co-operation much further than have social animals.

9. Though beavers live in apartment houses, each beaver works only for its own comfort and safety.

10. Human society is the only society that has a division of labor.

11. There are many more carnivorous than herbivorous animals on earth.

12. In developing the United States, men have been very careful not to disturb the balance of life.

13. Wild life has not been damaged by civilization, because most wild animals have learned to adjust themselves to the changes which civilization has brought.

14. All the species of wild creatures which the white man attacked when he colonized America are now "coming back" because of modern methods of conservation.

Questions for Discussion

1. Do you think that competition among creatures of the same kind is generally more or generally less severe than competition between creatures of different kinds?

2. After the hurricane which struck New England in the fall of 1938, experts predicted that there would be a plague of tree-boring insects the following spring. Why?

Things to Do

1. Prepare charts showing some common food chains. Mark all the creatures that must kill before they can eat. Are the killers more or less abundant than the creatures that do not kill? Remember that herbivorous animals do not ordinarily kill the plants they feed on.

2. Read Maeterlinck's *Life of the Bee.* Some authorities believe this the best book on nature that was ever written.

3. Study the social life of ants. A community of ants can be bought or collected and kept in an observation nest. The nest can easily be constructed of wood. It should be rather shallow and should consist of two or three compartments connected by tunnels or runways. The glass cover should be close-fitting to prevent the escape of the ants. More complete directions for building the nest and for collecting and caring for the ants can be found in reference books in the library.

4. J. H. Fabre and W. M. Wheeler have written several books on the social insects. Try one of them. You may find it more exciting than a storybook.

5. Make a winter feeding station for birds and place it in some sheltered place near your school building. Keep it supplied with suet and sunflower seeds, and make a record of the different kinds of birds that visit it.

6. Write to your Fish and Game Commission and ask for a copy of the laws which protect the wild life of your region. Make a list of the creatures that have been given the greatest protection and try to understand why this has been necessary.

CHAPTER FOURTEEN

How Are Creatures Fitted for the Lives They Lead?

ADAPTATIONS TO THE WATER

What Adaptation Is. We have already seen enough of the living world to have observed how well both plants and animals are fitted for the lives they lead. Trees, grasses, birds, insects, and all other kinds of living things are suited not only to the things they do but to the places in which they do them.

Think of the mountain goat that can walk up a perilous cliff almost as easily as a fly walks up a wall. Think of the hawk that can soar all day on the wind. Think of the trout that can move through the swirling water of a mountain stream like a flash of light. Each of these creatures is perfectly fitted for the life it leads. The first is a perfect climber, the second a perfect flier, and the third a perfect swimmer.

Think, too, how different from one another the lives of these three creatures are. A goat, a hawk, and a trout are not at all alike. Climbing, flying, and swimming are not at all alike. Mountains, air, and running water are not at all alike. Yet the world is full of such different creatures doing such different things in such different places.

Think for a moment of yourself. You cannot live five minutes without breathing air. You are fitted for breathing air and you do it unconsciously, even when you are asleep. Breathing is just one way in which you and many other air-breathing creatures are fitted for life on the land.

It is just one example of *adaptation to environment.* "Adaptation" means "being fitted," and "environment" means "the surroundings."

In one way or another all living creatures are more or less automatically adapted to their environment, as you are adapted with the help of your lungs for breathing air. The variety and perfection of adaptations is one of the most amazing things in the living world. Let us examine some of the most striking adaptations in this chapter.

Exercise. Since you got out of bed this morning you performed a variety of tasks, such as dressing, eating, and walking. Make a list of these tasks, and try to explain how your body is adapted for performing them.

Life near the Surface of the Sea. Untold billions of one-celled plants and animals spend their entire lives drifting about in the sunlit surface waters of the oceans far from shore. Many much larger creatures live there too. Perhaps you remember that in Chapter III we studied the advantages of living in the water. We saw that all water-dwelling creatures are partly held up by the water and in other ways are fitted to live in it.

Study the picture of a jellyfish on the opposite page. Notice that the jellyfish is built like a parachute. Being built in this way, it gets the greatest possible amount of support from the water, just as a parachute gets the greatest possible amount of support from the air. Notice also that the jellyfish has no shell or bone to weight it down. Notice, finally, that the jellyfish lacks the strong tail which drives the salmon on long journeys through the sea.

In all these ways the jellyfish is *adapted* for a life of drifting in the *environment* of the open sea. Most of its companions in the same environment are more or less simi-

A. M. N. H.

The jellyfish moves through the water as a parachute does through the air

larly adapted. They are fitted for a life of lazy ease. They have not only water to support their bodies but wind to carry them from place to place and to blow food into their mouths.

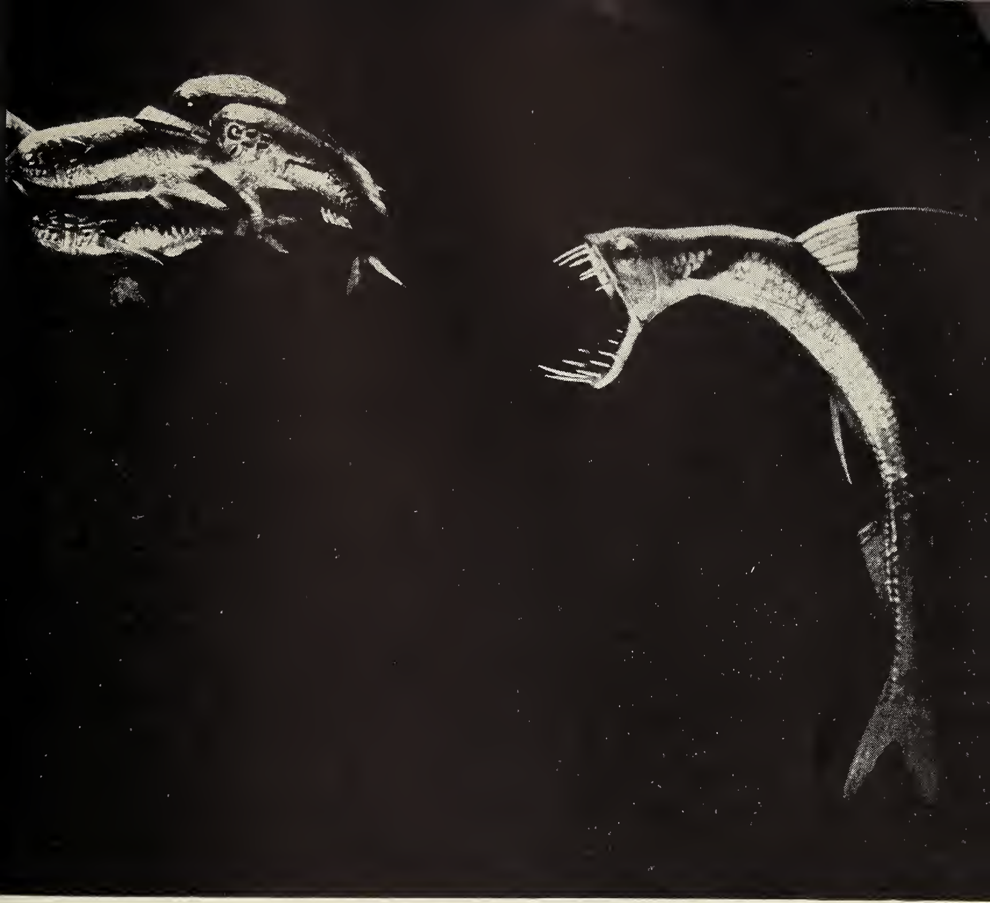
Life near the Bottom of the Sea. In imagination allow yourself to sink below the warm sunny surface waters of the ocean far from shore. Down, down you go, and colder and darker it becomes. Presently you have sunk about six hundred feet. It is as dark and cold as a winter night. You feel not the slightest movement of the waves, only the suffocating pressure of the water above you. Farther and farther you sink until you feel that you must certainly be near the bottom. You are a full mile below the surface of the sea, and the water is only a few degrees above the freezing point!

Then a strange thing happens. In the distance you see a tiny light. It grows larger and you decide that it must be drawing nearer. Then a form takes shape near the light. You can hardly believe your eyes. It is a fierce-looking little fish, but as gaily lighted as a Christmas tree! Presently you are surrounded by a variety of these deep-sea curiosities. Like lightning bugs and glowworms, the animals in this pitchy darkness are all equipped with lights which help them find their way through the darkness.

In the glow which is shed by your visitors you can see that some of them have great saucer-like eyes which help them to see what the light from their bodies reveals. Some have long feelers to help them find their way and remarkably large mouths to help them find their food. You marvel at the strange appearance of these creatures, as well you might. They are all wonderfully adapted to one of the strangest environments on earth.

Exercise. The photograph on the opposite page illustrates some of these deep-sea creatures. Examine them and list all the adaptations for deep-sea living which they show. What adaptation must all of them have which a picture cannot show?

Life along the Shore of the Sea. If you live near the sea, you know that the seashore is the home of many different creatures. Fishes of many sizes and varieties battle the surf. When the tide moves out and leaves the rocks uncovered, we find worms, starfishes, and barnacles clinging to the rocks or tangled in the seaweeds. Crabs run round on the sands of the beach while clams burrow safely beneath them.

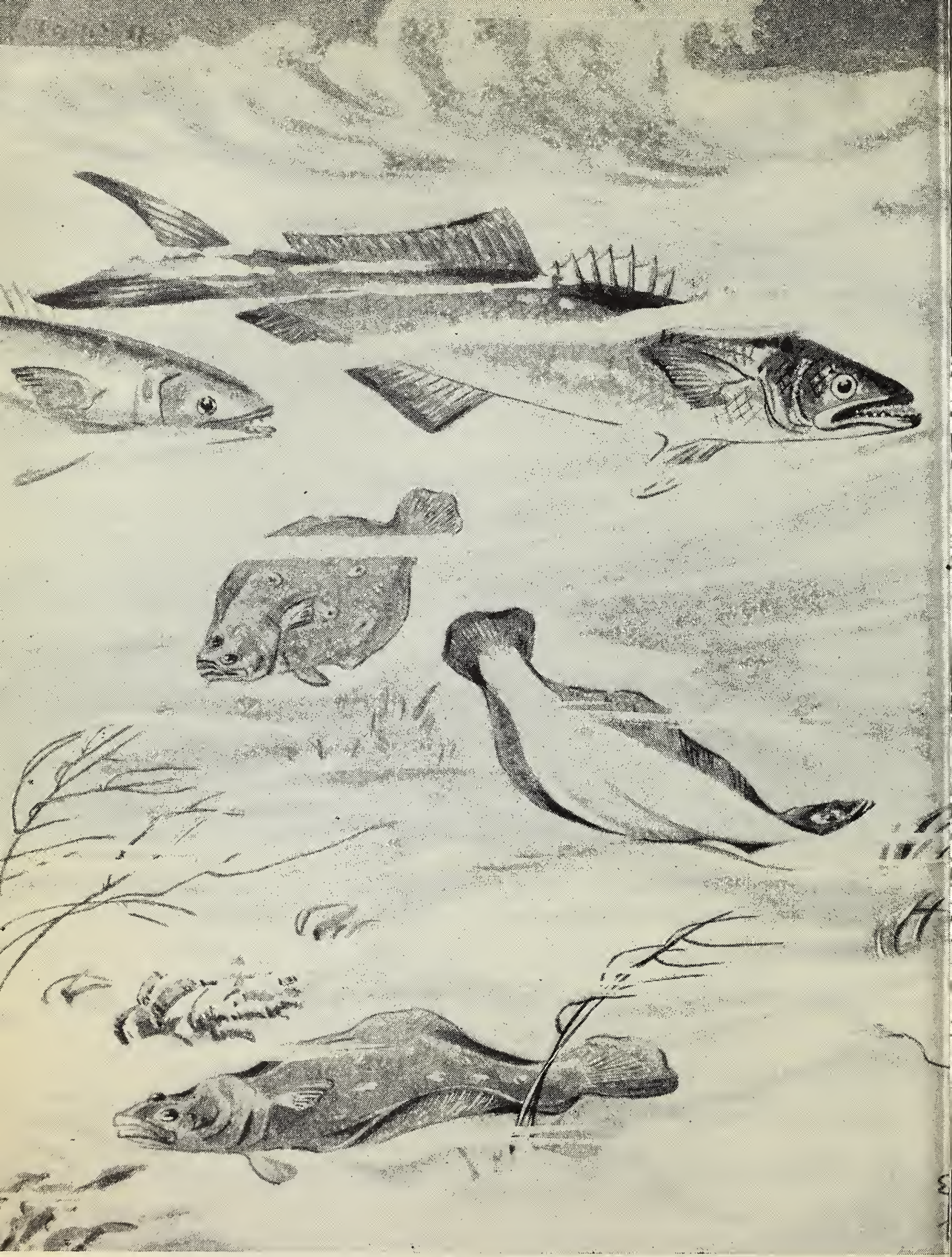


Photograph by L. Hess, A. M. N. H.

How should you like to be chased in the dark by this creature?

The seashore is indeed a world in itself. The creatures that live there show a multitude of different adaptations to a multitude of different conditions. Yet all the creatures that live in the zone that is swept by the tide and churned by the waves have one general adaptation in common. *In one way or another they all are built so that they cannot be crushed to pieces or carried away by the pounding and swirling water.*

The drawing on page 368 shows the bluefish that lives in the surf along the Atlantic coast. Notice that he is "streamlined" to the shape of a cigar so that he may cut through the water with ease. Notice the strong tail with which he



The bluefish is adapted to the surf, the flounder to the mud can drive himself along in the roughest weather. He is built for swift movement. Inside his body there is a strong but flexible skeleton to strengthen him against the waves, currents, and tides of his environment. Do you see what a different life the bluefish lives from that of the lazy drifters farther away from the shore?

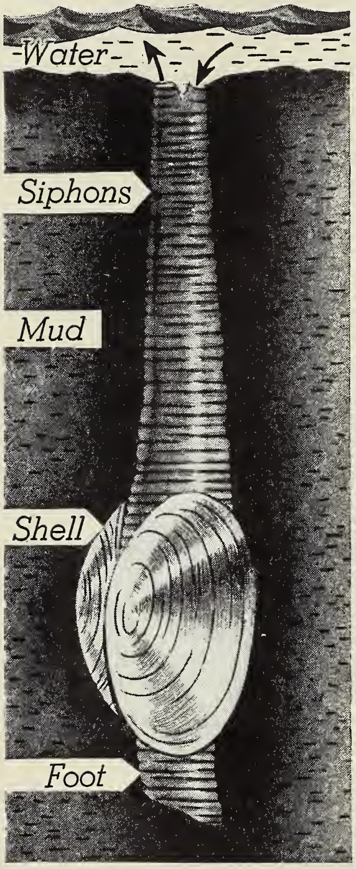
The drawing also shows the flounder, a neighbor of the bluefish in the shore waters of the Atlantic coast. Notice that the flounder is more like a pancake than a cigar. He is adapted for lying on the bottom beneath the waves. While the bluefish is vigorously darting round in search of food in the water, the flounder is quietly nosing through the sand and mud. He spends most of his life lying on one side and if he had a downside eye, it would normally be buried in the mud. But he has no downside eye. Both are on the upside, as you can see in the illustration. The flounder can remain flat on the bottom resisting the tug of the water and at the same time have the use of two eyes to watch the approach of enemies or food from above.

Many different creatures make their homes on that part of the shore which, when the tide is low, is exposed to the air and, when the tide is high, is covered with swirling water. Some of these creatures live on rocky shores. The barnacle shown at the right is one of these creatures. Notice that it is strengthened against the pounding of the waves with a stony shell. Notice that it is also protected against the drag of the tide with a sucker-

The barnacle is adapted for life on tide-swept rocky shores

Drawing after photograph by Cornelia Clarke

like attachment. In this way the barnacle may live without danger of being pounded to pieces on the rocks or of being dragged out into the open sea.



The clam is adapted to sandy and muddy seashores

The drawing on the left shows a clam that is adapted for life on the sandy and muddy parts of the seashore in the tide-swept zone. By burrowing in the sand or mud, the clam escapes the unending wear and tear of the water. Notice the "foot" with which he digs his burrow. Notice the siphon through which water and food are drawn into his body, and the other siphon through which waste is thrown out.

Do you see how all these creatures of the seashore are adapted in one way or another for fighting the water?

Exercise. If you live near the seashore, make a collection of as many different shore creatures as you can find. If you do not live near the seashore, make a collection of pictures showing shore creatures. Explain how each one is adapted for the life it lives.

Life in Fresh Water. In explaining the world of water in Unit II, we met several of the inhabitants of lakes and ponds. It would be well to review Chapter III of that unit, because it contains information which will help you understand the adaptations of fresh-water plants and animals.

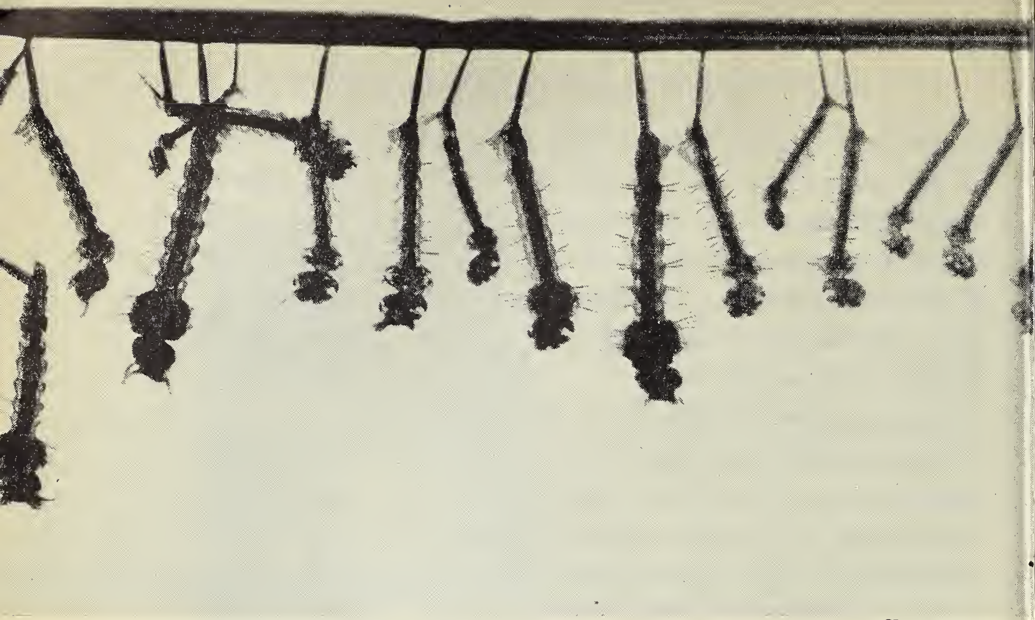
The creatures that live in lakes and ponds are not forced to fight the water as vigorously as are those that live in rivers and brooks. The inhabitants of lakes and ponds are likely to be weak and lazy.

Have you ever noticed how the surface of the water in a drinking glass turns up round the edge and sticks to the inside of the glass? It does so because the *surface of all water is an elastic film which is tougher than the water underneath*. A great many creatures that spend their lives in lakes and ponds are adapted to this film in one way or another.

The photograph below shows a group of "whirligig water beetles" that use the film as a skating rink. The weight of this insect is adapted to the film so that no matter

Whirligig beetles skate on the surface film of pond water

Lynwood Chace



Hugh Spencer

Mosquito larvae ("wigglers") hang from the lower surface of the water film

how vigorously he skates, he will not break through and drown. The photograph above shows how the larva of a mosquito hangs from the underside of the film with its breathing parts exposed to the air. The drawing on page 68 shows a water lily that uses the film to float leaves which the weak stems could not support without this help. Many other creatures of lakes and ponds are adjusted to the surface film in a similar manner.

In the running water of rivers and brooks the surface film is frequently broken. Creatures generally must be strong enough to support themselves without help from the film, and to hold their places in the current. Like the creatures that live in the ocean surf, many inhabitants of running water are styled for power and speed. In swift-flowing mountain brooks, for example, we find the swift-moving trout. We also find many plants, worms, and insect larvae with the ability to attach themselves securely to the bottom so that the current will not carry them away.

Exercise. If you did not make an aquarium when you were studying Chapter III, do so now. You will find directions on page 58. Every plant and animal you put into the aquarium will be related in some way to the surface film of water. Study and explain these relationships.

Many fresh-water creatures, of course, live entirely beneath the surface film and are not specially adapted for using it. Every creature, indeed, has its own adaptations for its own way of life. You might study ponds and rivers as long as you live and you would still not discover all the adaptations of their inhabitants.

ADAPTATIONS TO THE LAND

The Business of Living on Land. There is a much greater variety of conditions on the land than in the water. There are mountainous lands and flat lands, forest lands and grass lands, wet lands and dry lands, cold lands and hot lands. Creatures living in each type of land have their own special types of adaptations. So far as animals alone are concerned, however, they must become adapted to the land in one or more of the following ways. They must be (1) walkers or runners, (2) burrowers, (3) climbers, or (4) fliers.

Walkers and Runners. Because food is likely to be scattered widely and unevenly over the lands, most animals have to be constantly on the move. Walking or running is the commonest type of movement among animals of every land. The photograph on page 374 shows an animal in which this type of movement, or *locomotion,* has reached perfection.

One summer some years ago one of the authors of this book was hunting for oil on the sagebrush plains of

Wyoming. Small herds of antelope lived on these plains. We could approach them in our automobile, but only to within a hundred yards or so. Then the antelopes would break into a run, and we would follow.

By dodging clumps of sage and badger holes, we could drive the car over the hard surface of the plain about forty miles per hour. When the herd scattered, we would give chase to the largest male. He would lope along just in front of the car at forty miles an hour without any noticeable effort, looking back at us from time to time and apparently enjoying the game. In time, however, he seemed to grow bored. He would then bound away from us as if he had been shot out of a gun—at nobody knows how many miles per hour.

Antelopes, horses, and many other creatures of the plains are marvelously adapted for walking and running. Every bone and muscle in their bodies is shaped to this purpose.

The antelope is perfectly adapted for running

© Charles J. Belden, $\frac{Z}{T}$ Ranch

The mole is a champion burrower

Exercise. Study the picture on the opposite page and list the ways by which the body of an antelope is adapted for running. Name half a dozen creatures that have more or less similar adaptations.

The streamlined body of an antelope or a race horse is a remarkable adaptation for locomotion on the ground. But it has its disadvantages. An animal that must use all four limbs in locomotion may be handicapped in a fight with an enemy. It can never use its limbs as instruments for improving its mind. If men had had to go about on all four limbs throughout their lives, they probably would never have become civilized. With their hands free from the business of locomotion, they were able to make discoveries and inventions, and to rise above animal savagery.

Burrowers. Not all animals of the land move actively about on its surface. Like the clam of the seashore, many land animals live in burrows beneath the ground. The illustration above shows a mole, a typical burrowing animal.

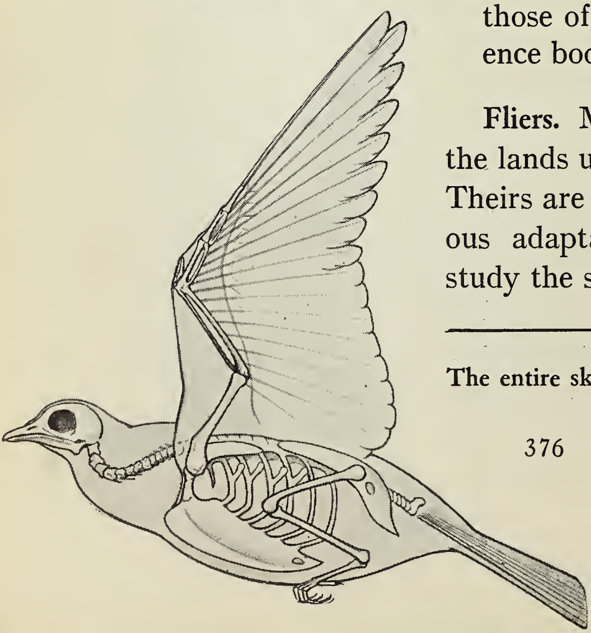
Notice that his eyes and tail are poorly developed because these organs are useless underground. Notice that his front claws and teeth are very sharp because these organs are needed for digging.

Exercise. Think of as many different kinds of burrowing land animals as you can. Explain how each one is adapted for the life it leads. Are these adaptations like or unlike the adaptations of the mole? If you cannot think of any burrowing animals or remember their appearance, use a reference book on animals to help you with this exercise.

Climbers. Many animals spend their lives climbing over rocks or climbing and swinging in trees. The photograph on the opposite page shows a gibbon, perhaps the finest acrobat in the entire living world. He can clear as much as forty feet in a single swing, and he never misses his mark. Notice how beautifully the gibbon is fitted for his vigorous life. He is lean and tough, but at the same time his chest and shoulders are very powerful. His arms are long and strong, with hooklike hands for grasping the branches.

Exercise. Think of as many different kinds of climbing land animals as you can. Compare their adaptations with those of the gibbon. Use a reference book if you need its help.

Fliers. Many animals that live on the lands use the air for locomotion. Theirs are perhaps the most marvelous adaptations of all. Carefully study the skeleton of the bird which



The entire skeleton of a bird is modeled for flight

Photo by S. Washburn, A. P. E.

The gibbon is the finest acrobat on earth is pictured on page 376. Notice how the front limbs or wings are built for sweeping through the air. Notice the breastbone and the rudder-like tail with which the bird both balances and steers. Add feathers, which catch the air, and hollow air-filled bones, which reduce the weight, and you have the most efficient airplane that was ever designed.

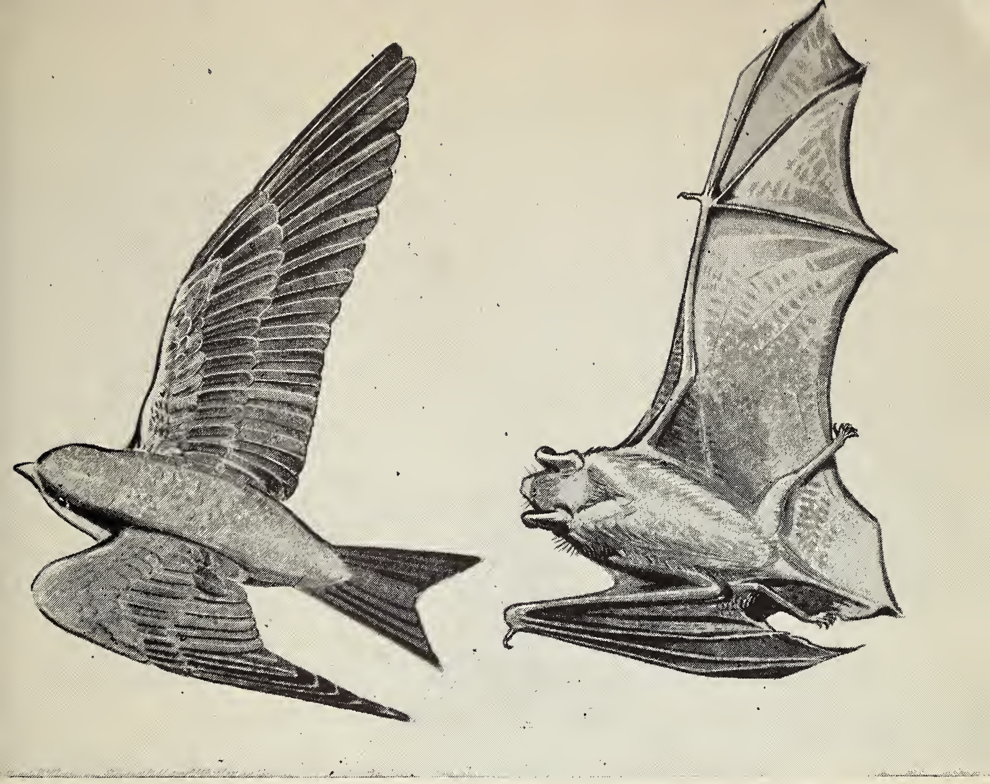
Exercise. Compare the wing of a bat with the wing of a swallow, as shown on the opposite page. What are the differences? Which is the better organ of flight?

Though all land animals must be adapted for running, burrowing, climbing, or flying, they all have other adaptations as well. All living creatures in a given region, for example, must be adapted to the climate of the region. We may broadly divide the lands of the earth on the basis of climate into four very different environments: (1) the cold polar regions, (2) the temperate regions, (3) the wet tropical regions, and (4) the dry deserts. What adaptations do creatures make to each of these four environments?

ADAPTATIONS TO DIFFERENT CLIMATES

The Polar Regions. If you were an Eskimo in the land of the midnight sun, your ways of living would be very different from what they now are. You would enjoy the long bright summer when the sun drops close to the horizon each night without ever sinking beneath it. You could fish and pick berries every day for as long as you liked. During this season you and your family would live happily in a tent.

In winter, however, things would be much less pleasant. The sun would rise above the horizon for only a few hours each day. Like the animals around you, you would have a hard time keeping warm and finding food. You would



Notice the differences between the wings of bird and bat

give up your summer tent and move into warmer quarters. You would put on your warmest clothing, and your mother would sew you into it. Your father and mother would gather as much food and fuel as possible in preparation for a long, long period of bitter cold.

If you lived in this region, you would be familiar with plants and animals far different from those you now know. In the summer you would watch the seals sunning themselves on the rocks. You would also see hares and foxes. You might even see a polar bear, walking noiselessly on his padded hairy feet, sneaking slowly but surely closer to a little northern fox. You might later see the bear tear his victim to pieces. At other times you might see him scooping a fish out of the water, or picking berries with his clever paws.

You might also see many wild ducks, geese, and other kinds of birds which had come with summer from the south. You might watch them eating berries, seeds, and insects. You might see their nest and their young. The foxes eat both birds and rabbits, while the polar bear eats all three—with a few seals and fish thrown in for good measure.

With the coming of cold weather you could watch the animals change in many ways. Their fur grows thick, soft, and warm in winter. Hares that are brown in summer turn white in winter. Foxes that are bluish in summer also turn white in winter. When animals match the color of their environment in this way, they are less easily seen by their enemies. We say that they are *protectively colored.* Many animals in many parts of the world are colored in a similar way to match their background.

Exercise. List all the animals you have seen which are protectively colored to a high degree. Are these animals more or less abundant in your neighborhood than the animals which stand out against their background?

Many of the birds that nest in the Far North are able to travel long distances. When the cold weather comes and food is scarce, they fly south. Many of the insects of the polar regions die when winter comes. They lay eggs before they die, however, and young insects hatch out the following spring. Many plants die after producing their seeds, but the seeds live through the winter.

Plants cannot grow to any great height in the polar regions because the summer period of growth is very short. When plants are scarce, land animals must depend very largely on other animals for food. The polar bear, a good swimmer and a skilled fisherman, gets most of his winter meals from open places in the ice which covers the sea. In

National Museum, Canada

How should you like to be sewed into your clothes for the winter?

these watery holes fish and seals are plentiful. The cold air and water do not worry the polar bear because his thick coat of fur protects him from both.

The seals, with a thick layer of fat under their skin, seem quite comfortable as they slide through the icy water, hunting the fish on which they feed. The fish, in turn, eat smaller fish or other forms of animal life, and these, in their turn, eat the tiny water plants.

So we see that there are many different kinds of living creatures in the polar regions. The difficulties of their lives do not disturb them because they are adapted to meet these difficulties. In one way or another they are adapted to the cold.

The Tropical Regions. Let us skip the temperate regions for the time being and go directly to the tropics. Suppose we take a trip across the Atlantic Ocean to Africa. Let us then take a canoe up the Congo River into the wet forests and jungles which extend almost entirely across the continent near the equator. As we paddle up the river we brush against the lower branches of the trees that form a leafy arch above our heads. Vines twine around the trunks like gigantic snakes, and hang down almost to the water. Gaily-colored parrots squawk as they fly from branch to branch, and monkeys chatter far above. How different this green world is from the white world we have just explored!

There are many snakes in this tropical jungle, and countless insects that we do not see because their colors match those of the trunks and the leaves. There are many savage-looking crocodiles in the water and on the shores. A mother hippopotamus swims across the river ahead of us with a young one on her back.

Presently we paddle round a bend in the river, and there at the water's edge is a herd of elephants! Their color, too,

Plants battle for light in the tropical jungle

is nearly like that of the tree trunks and the patches of shadow among the trees. We do not see the spotted leopard hiding among the sun-dappled leaves above us because he matches his background even better than do the elephants. These and many other jungle creatures are protectively colored to a high degree.

Plant life in the moist climate of the Congo valley seems almost without any limit. There is no cold season; so growth can continue the year round. There is plenty of water—too much for comfort at times; for the tropics have long rainy seasons. Under such conditions *the chief enemies of plants are other plants.* They must compete with one another in lifting their leaves to the light, and only the tall and rapidly growing ones can win. The others must die by millions in the soggy, dark prison of the jungle floor.

Where plant life is so plentiful, a great many animals are adapted for living entirely on plants. An elephant, for example, never eats animal food. He browses on young bamboo shoots and the tender leaves of trees. He digs up roots and tears down branches with his tusks. On cloudy or rainy days he may risk browsing in the open. When he has eaten the choicest food in one place, he moves with his herd to another place in search of a new supply.

Thus, in one way or another, tropical creatures are adapted for a life of

This citizen of tropical waters means what he says

H. Armstrong Roberts

sunlight and warmth just as polar creatures are adapted for a life of darkness and cold.

The Desert Regions. Along the outer edges of the tropical regions in Asia, Africa, and North America there are lands which in summer may be as hot as the jungles which lie closer to the equator. They are very different from the jungles, however, because they are as dry as an old piece of leather. These are the deserts of rock and swirling sand.

One of the surprising things about the desert is the number and variety of creatures that manage to live there in spite of the dryness. Most desert plants spend the largest part of their lives underground in the form of seeds, bulbs, and fleshy roots. During the few wet weeks of spring, however, they come up to the air. Then, as if by a miracle, the brown dead face of the desert lights up with the bloom of countless flowers. The picture on the opposite page shows one of the most marvelous sights in the world—a sand dune covered with many beautiful flowers.

Several kinds of desert shrubs and trees do not retreat into the ground during the long dry months of the desert year. The photograph on page 386 shows some of these hardy plants. All these plants are marvelously adapted for preserving the moisture which their roots are able to absorb from the stony ground.

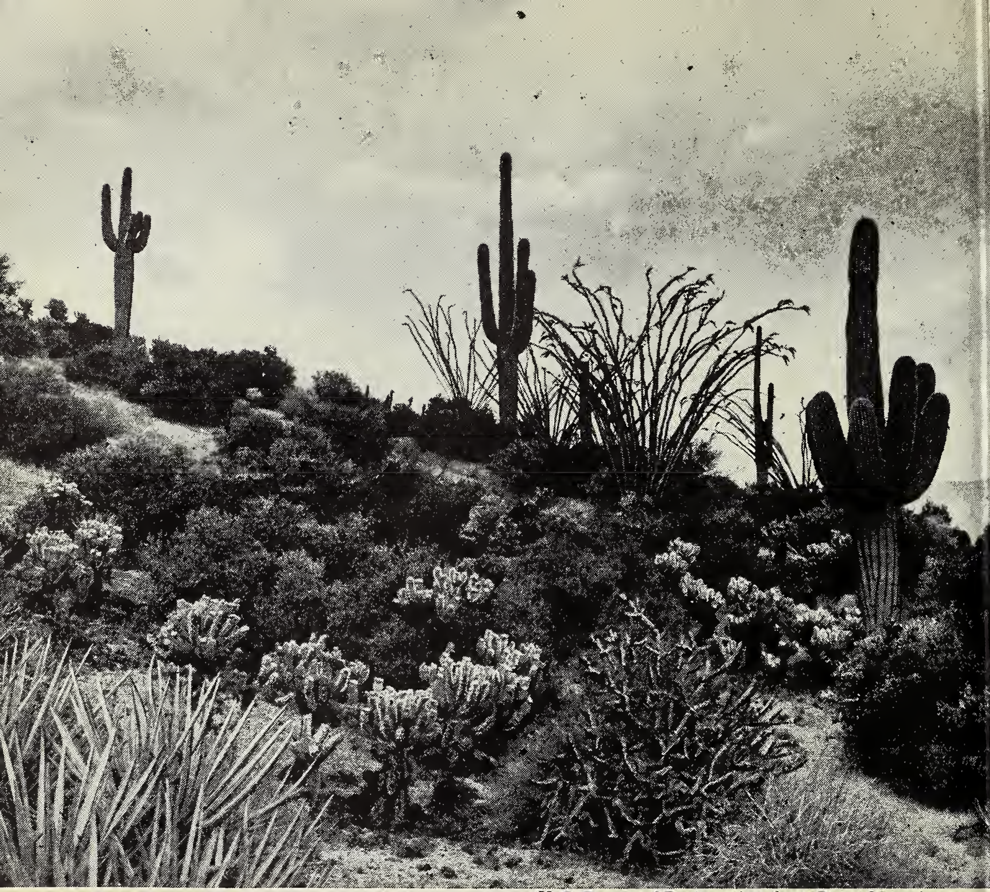
The illustration on page 387 shows the roots and branches of a desert bush. Notice how long the roots are in proportion to the parts above, an adaptation for gathering the scanty and widely distributed moisture from the soil. Notice how small and spiny the leaves are. *To preserve moisture which normally leaks out of the leaves and into the air, desert shrubs and trees have transferred most of the business of*

Frasher's

In spring the face of the desert lights up with the bloom of flowers

the leaves to the trunk and branches. These parts expose less surface to the dry air, and therefore are less wasteful of the precious moisture.

Like the plants, the animals of desert regions are adapted for a life of dryness. One of the authors of this book once had a pair of kangaroo rats for pets. These strangely gentle little creatures hop round on their hind limbs like kangaroos. They live entirely on seeds and such leaves as they can find on the desert floor. The pair which your author held captive for a year never accepted the offer of a drink in all that time. They were happy and healthy on the moisture which their food contained.



U. S. Bureau of Reclamation, from *Desert Magazine*

The shrubs of the desert are spiny and almost leafless

Kangaroo rats and many other desert animals live in burrows. They come out to feed only after the blazing sun has set. For this reason many people have thought the deserts uninhabited. More careful observers now know that a great many different kinds of animals live in these unfriendly places. Like creatures of other regions, they are adapted in one way or another for the lives they lead.

The Temperate Regions. The temperate regions, where most of us live, are generally free from the prolonged cold of the polar regions, the prolonged wet heat of the tropical regions, and the prolonged dryness of the deserts. The temperate regions, however, frequently suffer shorter periods of all three of these extremes. *Plants and animals are accordingly rather generally adapted to frequent and violent changes in weather conditions.*

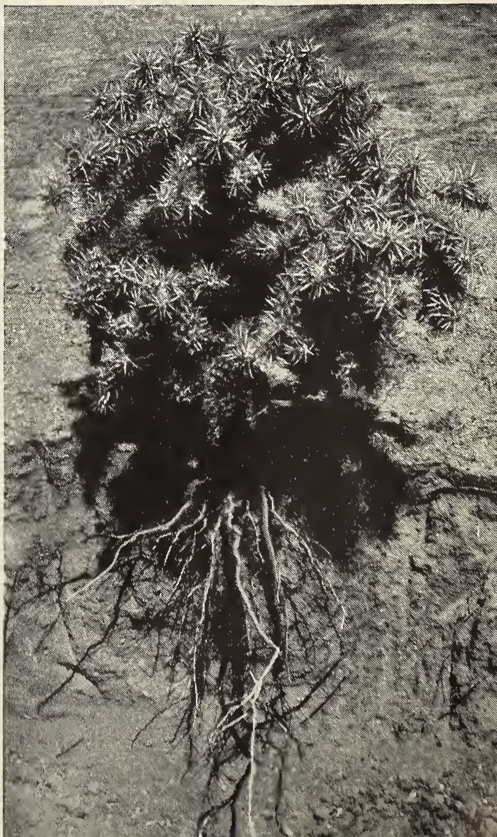
Forests and pastures change with the seasons. With the coming of fall these places take on a very different appearance. The leaves of plants (excepting those of the evergreens) lose their green color. Grasses and weeds turn brown. Seeds ripen in their pods. Wild fruits, acorns, and nuts fall to the ground. All living processes in the world of plants are either slowed down or stopped.

Animal life also changes with the approach of winter. Most adult insects are killed by the cold nights, but they lay their eggs before this happens. The eggs of the grasshopper remain on or in the ground all winter and then hatch out in the following spring. The eggs of moths and butterflies are laid during the summer and hatch into larvae which can endure the cold. Several kinds of insects spend the winter as pupae. A few insects, including the bumblebee and the housefly, are tough enough to live through the winter as adults.

When winter approaches in north-temperate regions, many birds travel (*migrate*) to the south. The robin, bobolink, blackbird, thrush, swallow, brown thrasher, wren, and many others belong to this group.

Desert plants have very long roots

J. G. Brown



U. S. Bureau Biological Survey

Many birds change their residence with the seasons

Some of these birds travel far. Robins stop in the states along the Gulf of Mexico, but the bobolink journeys as far as the valley of the Paraguay River in South America. The distance between the northern and southern homes of birds may be as much as five thousand miles.

With the coming of winter, field mice, gophers, hedgehogs, bears, skunks, and many other animals retreat into burrows. Some of these animals lay up a supply of food in their dens. Others sleep through the winter, nourished by the fat which they have stored up in their bodies. We say that these sleepers *hibernate*, which means that they spend the winter in a state of inactivity.

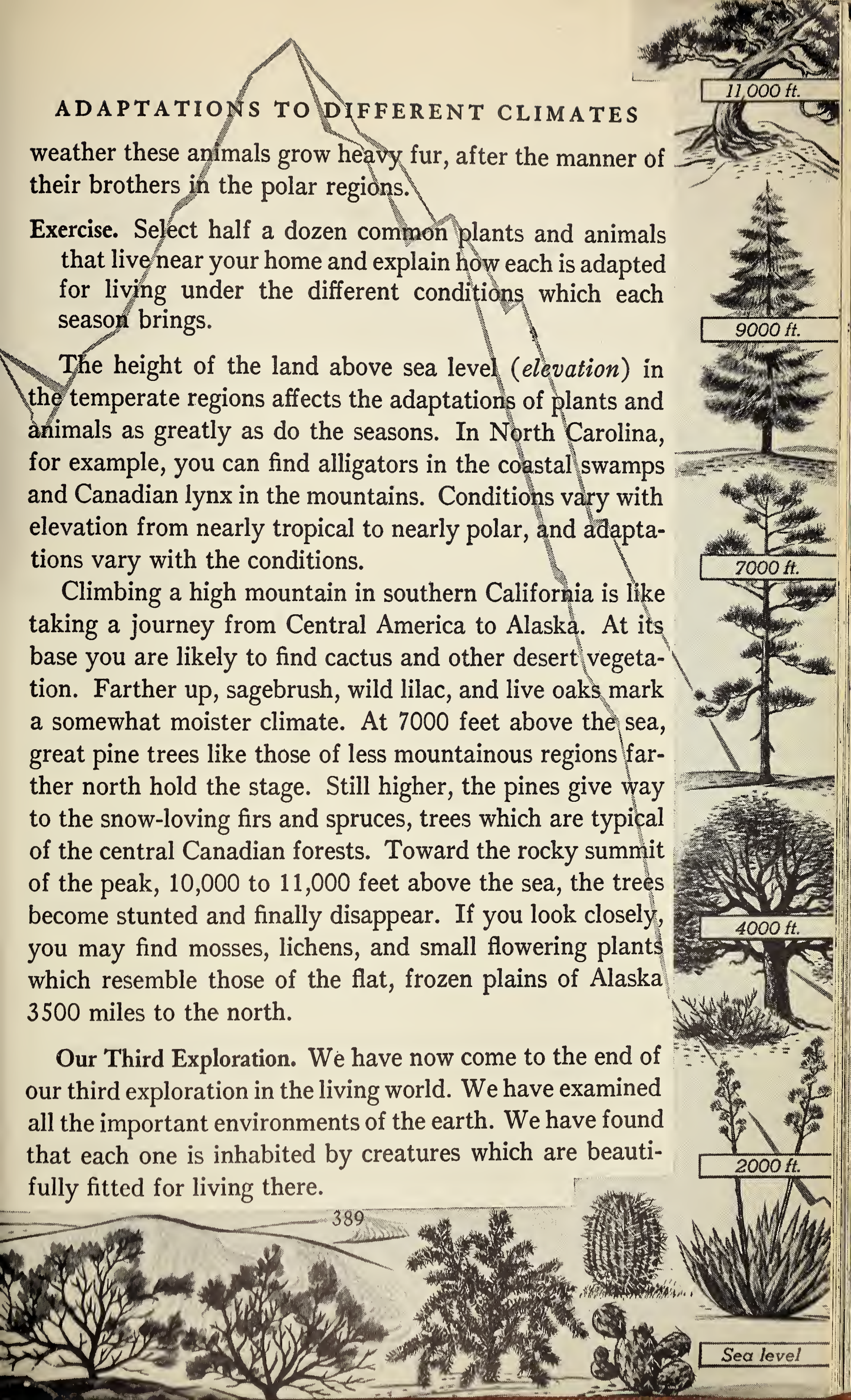
Some animals remain active and continue their search for food throughout the winter. If there is snow on the ground, you may see the tracks of rabbits, squirrels, opossums, raccoons, minks, and foxes. With the coming of cold weather these animals grow heavy fur, after the manner of their brothers in the polar regions.

Exercise. Select half a dozen common plants and animals that live near your home and explain how each is adapted for living under the different conditions which each season brings.

The height of the land above sea level (*elevation*) in the temperate regions affects the adaptations of plants and animals as greatly as do the seasons. In North Carolina, for example, you can find alligators in the coastal swamps and Canadian lynx in the mountains. Conditions vary with elevation from nearly tropical to nearly polar, and adaptations vary with the conditions.

Climbing a high mountain in southern California is like taking a journey from Central America to Alaska. At its base you are likely to find cactus and other desert vegetation. Farther up, sagebrush, wild lilac, and live oaks mark a somewhat moister climate. At 7000 feet above the sea, great pine trees like those of less mountainous regions farther north hold the stage. Still higher, the pines give way to the snow-loving firs and spruces, trees which are typical of the central Canadian forests. Toward the rocky summit of the peak, 10,000 to 11,000 feet above the sea, the trees become stunted and finally disappear. If you look closely, you may find mosses, lichens, and small flowering plants which resemble those of the flat, frozen plains of Alaska 3500 miles to the north.

Our Third Exploration. We have now come to the end of our third exploration in the living world. We have examined all the important environments of the earth. We have found that each one is inhabited by creatures which are beautifully fitted for living there.


11,000 ft.
9000 ft.
7000 ft.
4000 ft.
2000 ft.
Sea level

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your correction.

1. The jellyfish is shaped like a bullet so that he can drive himself swiftly through the surface waters of the sea.

2. Below six hundred feet the oceans are still, cold, dark, and lifeless.

3. Because the flounder is flat, he is well adapted for a life of drifting at the surface of the oceans.

4. Barnacles are common inhabitants of sandy seashores.

5. Clams have strong, sucker-like attachments with which they cling to the rocks along the seashore.

6. There are no similarities between animals that live in rivers and animals that live in the oceans.

7. There are fewer different kinds of adaptations among land animals than among water animals, because conditions on land are everywhere much the same.

8. Moles and other burrowing animals have large eyes to enable them to see as well as possible in their dark dens.

9. There are very few plants and animals in the polar regions because of the extreme cold.

10. All the animals in the polar regions but few animals elsewhere are protectively colored.

11. Plants are so abundant in the tropical regions because these are the only places in the world where plants have no enemies.

12. Though flowers are abundant on the desert during the spring, animals are always rare.

13. Because the climate is so mild in the temperate regions, neither the plants nor the animals of these regions show any special adaptations to climate.

14. When birds fly south in the winter, we say that they hibernate.

Questions for Discussion

1. Discuss with your classmates each of the environments you have studied in this chapter. Do you believe that in each environment there is one adaptation which is more important than all other adaptations for the creatures that live in the environment? If so, why is it more important?

2. Discuss the advantages and disadvantages of living in the different climatic regions. Consider food, warmth, and any other things that seem important. If you were a bear, where should you prefer to live? If you were a lizard, should you want to live in the same region?

Things to Do

1. Make a drawing of a scene as you would imagine it in the depths of the ocean, in the desert, or in any of the other environments you have studied in this chapter. Be sure to include a few typical living creatures.

2. Collect pictures showing life in the different environments of the earth. Arrange them neatly in a scrapbook.

3. Make several field trips in your neighborhood to discover examples of protective coloring in plant and animal life. Keep a careful record and illustrate your report with photographs or original sketches.

4. In any museum you will find "habitat groups," exhibits of plants and animals that live together in one par-

ticular region. If you have collected any specimens or if you are good at making models, you may want to make a habitat group for your classroom or school museum.

5. William Beebe has written several interesting books about plants and animals that live in different environments. *Beneath Tropic Seas* is a fascinating record of diving for specimens among the coral reefs of Haiti. *Jungle Days* is a fine picture of life in tropical regions. Another interesting book on the habits and adaptations of many different creatures is *Animals of Land and Sea*, by A. H. Clark.

CHAPTER FIFTEEN

What Part Does Food Play In Our Lives?

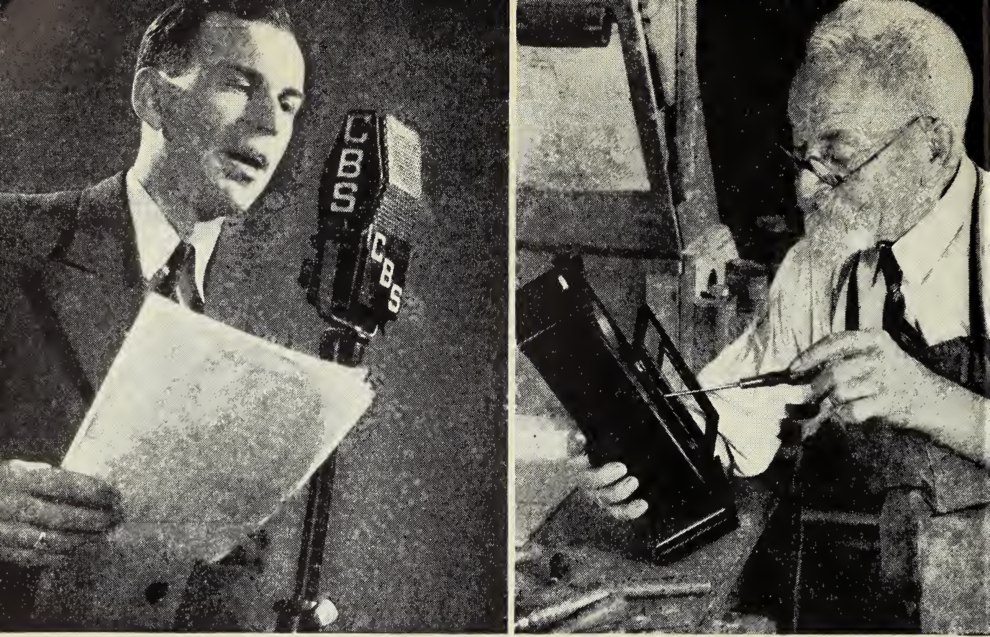
OUR ADVANTAGES IN THE LIVING WORLD

Our Place in the Living World. So far in discussing the world of living creatures we have said much about plants and animals but little about ourselves. Though as human beings we are very different from all other living things, we yet must eat, protect ourselves, and reproduce. We must fit into the web of life and adapt ourselves to our environment. In other words, we too are part of the living world. As such we deserve at least one chapter in this unit.

Three things in particular make us different from all other living creatures. *First, we have much the best brain in the world.* With the help of our brain we can adjust ourselves better, and to a greater variety of environments, than can any other living thing.

Second, we have much the cleverest front limbs in the world. Our hands are second only to our brain in helping us with our adaptations. With our hands as partners of our brain, we can make the discoveries and inventions which spell civilization. If you want a good example of the importance of hands, think of the observations and experiments you have made in connection with the first fourteen chapters of this book. How many of these would have been possible if you had had no hands to help your brain?

Third, we have much the most remarkable larynx in the world. The larynx is a little box in our throat which vibrates very much like the loud-speaker of a radio, and in



Galloway; Keystone

Our voice and hands are partners of our brain

doing so produces sound. The human larynx can make a greater variety of sounds than any other instrument in the world. By agreeing to attach certain meanings to certain sounds, men invented speech. By means of language, first spoken and then written, they were able to communicate and preserve their thoughts, discoveries, and inventions.

Brains, hands, and larynx, in short, have made us the rulers of the living world. They have rid us of most of our natural enemies. They have enabled us to invade and conquer every land area on the globe. *In other words, they have made us the safest, freest, and most comfortable creatures on earth.*

The Risk of Making Mistakes. These great advantages, on the other hand, have increased our responsibilities. By being freer than other creatures to do as we wish, we are also freer to make mistakes. In no other department of our lives are we more likely to make mistakes than in the department of eating. We have the richest and most varied diet in the living world. How healthy and happy we shall be depends to a great extent on how wisely we use it!

The Richness and Variety of Our Diet. Think of the animals that spend their lives in your neighborhood. The rabbit must be content with such leaves and green shoots as he can find within a few hundred yards of his burrow. The squirrel must get along on the seeds, berries, and nuts he can gather in a similar limited area. The mosquito can never vary its diet of plant juices and blood, the fox its diet of meat, nor the bee its diet of nectar and pollen.

Think then of yourself. You eat food of every variety from all over the world. This morning, when you sat down to breakfast, you may have found grapefruit or oranges from Florida, Texas, Arizona, or California. You may have found cereal from the Middle Western plains, milk from a near-by farm, sugar from the West Indies, and cocoa from Brazil.

Tonight when you sit down to dinner you may find beef, lamb, or pork from the Middle West, perhaps fish from the ocean a thousand miles away. There will doubtless be salt, probably from mines in New York State, and pepper from the tropics. There may be potatoes which were grown in Idaho, Long Island, or Maine, and vegetables from the South. There may be olives from Italy. The dessert may have come from any number of different places. Bananas, coconuts, dates, apricots, peaches, rice pudding, tapioca, raisins—what far corners of the earth these things suggest!

Exercises. Visit a grocery store and make a list of the different kinds of canned fruits and vegetables you find there. Opposite the names in the list write the names of the places where the different fruits and vegetables came from. The grocer will probably be glad to help you if he is not too busy.

Visit a meat market and make a list of the different kinds of meat, fish, and shellfish which are displayed there. Determine, as you did in the grocery store, where each kind came from.

How Science Helps Us with Our Eating. Science has played an important part in making such a varied diet both possible and safe. Not so long ago our food supply depended largely on products which came from our near-by neighborhood. Fresh fruits and vegetables were unknown during northern winters. Today, however, fast steamers, express trains, and airplanes rush such perishable foods to all our large cities and to nearly all our smaller communities. Not only do iced freight cars carry perishable foods long distances without danger of spoiling, but automatic refrigeration protects these foods after they have arrived.

More than this, our food supply is protected through strict inspection by national and city authorities. Severe punishment is handed out to canners and merchants who fail to observe proper sanitary precautions. Most canned foods reach the kitchen without having been touched by a human hand. Most fresh foods, such as meats, fruits, and vegetables, are as far as possible kept under glass, in huge refrigerators, or at least under netting and away from insects, dirt, dust, and careless handling by customers. The milk we drink must meet certain strict standards of purity, and the eggs we eat are graded. No longer do we need to fear, as people once did, the dangers of spoiled or impure food.

Robert Yarnall Richie

The modern grocery store is a treasure house of good and healthful things to eat

THE THREE GREAT CLASSES OF FOODS

An Embarrassment of Riches. With all the lands and waters of the earth laying their riches at our feet, we may well be puzzled in deciding what gifts to accept. We know from sad experience that some foods do not agree with us, that *our appetites alone will not lead us to a proper diet.* We know that we must be guided by intelligence as well as hunger in our eating.

Science has proved by many observations and experiments that to be healthy we must do more than merely avoid the foods which we know do not agree with us. We must do more than merely eat such foods as do not make us ill. *We must also properly combine our foods so that our bodies will regularly receive a variety of things which they need.*

The greatest danger of having so many tasty foods to choose from is that we shall not combine them correctly. Even today a great many people are starving in a world of plenty. They are starving, not because they are not getting enough to eat, but because they are not eating the right combinations of food.

Science has proved that there are three great classes of foods which human beings must eat in proper combinations in order to remain alive and healthy. These three great classes of foods are the *carbohydrates*, the *fats*, and the *proteins.*

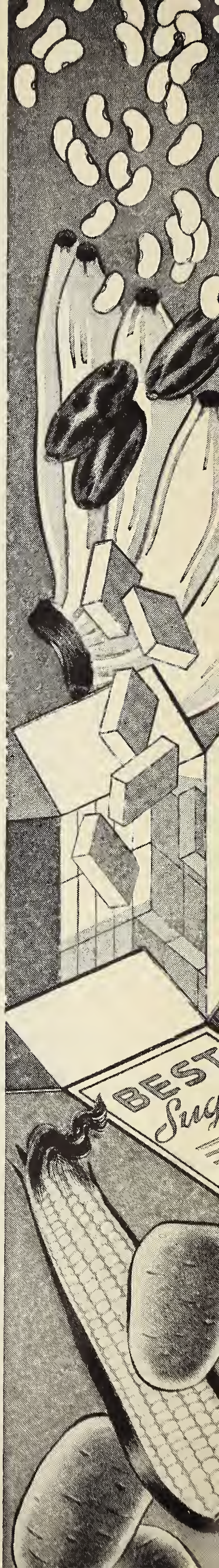
The Carbohydrates. You have already seen that green plants make sugar from carbon dioxide and water. This sugar circulates in the sap to the living cells in all parts of the plant. It may be changed into starch and stored in the leaf, as in lettuce, spinach, and other leafy vegetables. It may be carried to stem or root and changed into starch there, as in potatoes and other root vegetables. Seeds of plants—wheat, barley, rye, oats, corn, and rice—are a main source of food for men and animals. Seeds, like vegetables, are composed very largely of starch.

Because sugar and starch are made of carbon, hydrogen, and oxygen, they are called carbohydrates. The "carbo" in this term refers to carbon, and the "hydrate" to water, which is made of hydrogen and oxygen.

Carbohydrates are known as *energy foods*. Energy gives us the power of doing such things as walking, talking, running, and breathing. Without energy we could not live; so the energy foods are very, very important. Like the coal in a boiler of a locomotive, they are the fuels that "make us go."

Few food products consist entirely of sugar or starch, but many contain much more of these compounds than do other foods. Study the table on p. 400, which shows the foods that are richest in the carbohydrates, sugar and starch. Observe that these foods consist largely of water but that the largest part of the remainder consists of carbohydrates. Most of our foods contain some carbohydrates, but those shown in the table contain high percentages of these energy-giving materials.

Exercise. How to determine the presence of starch in food: Apply a few drops of tincture of iodine to the freshly cut surface of a potato or other



These foods are rich in carbohydrates

These foods are rich in fats

vegetable. At the same time apply a few drops to a small sample of butter. The blue-black color which forms on the potato proves the presence of starch. The absence of this color on the butter proves the absence of starch.

Foods Rich in Carbohydrates[1]

	Percentage of Refuse as Purchased	**Percentage in Edible Portion**		
		Water	*Carbohydrates*	*Other Ingredients*
Banana	33.0	74.8	23.0	2.2
Bread (white) . .		35.3	53.1	11.6
Corn meal		12.5	75.4	12.1
Dates	10.0	15.4	78.4	6.2
Granulated sugar .			100.0	
Macaroni		10.3	74.1	15.6
Navy beans (dried)		12.6	59.6	27.8
Oatmeal		7.3	67.5	25.2
Potatoes	16.0	77.8	19.1	3.1
Raisins (seedless) .		17.0	80.8	2.2
Rice		12.3	79.0	8.7

A person who exercises a great deal needs more sugar and starch than does one who sits still most of the time. A football player, for example, needs more of these energy foods than a card-player, a child more than an adult. *One*

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[1] From Henry Clapp Sherman's *Food Products.* By permission of The Macmillan Company, publishers.

of the problems of proper eating is to get enough, but not too much, of the energy foods for the lives we lead. If you weigh considerably less than the average child of your age, height, and sex, or if you do not have the energy that other children have, it may be that you are not eating enough sugar and starch.

Foods Rich in Fats[1]

	Percentage of Refuse as Purchased	Percentage in Edible Portion		
		Water	*Fat*	*Other Ingredients*
Bacon	8.7	20.2	64.8	15.0
Butter		16.0	80.0	4.0
Cod-liver oil . . .			100.0	
Cream (whipping)		54.4	40.0	5.6
Fat meat (beef) .	1.0	28.0	62.0	10.0
Olive oil			100.0	
Peanuts	24.5	9.2	38.6	52.2

The Fats. Fats, like carbohydrates, are energy foods, though they give up their energy more slowly than sugar and starch. Like the carbohydrates, fats are made of carbon, hydrogen, and oxygen. Both carbohydrates and fats are not only used by our bodies to "make them go," but are also stored up by our bodies for future use. People who are too fat have stored up more of these food reserves than they will ever need. They should reduce the reserve by exercise. The best exercise for this purpose is the exercise of the will in the matter of second helpings.

Eating too much, however, is more often a mistake of parents than of children. Unless you are many pounds above the average weight of children of your own age,

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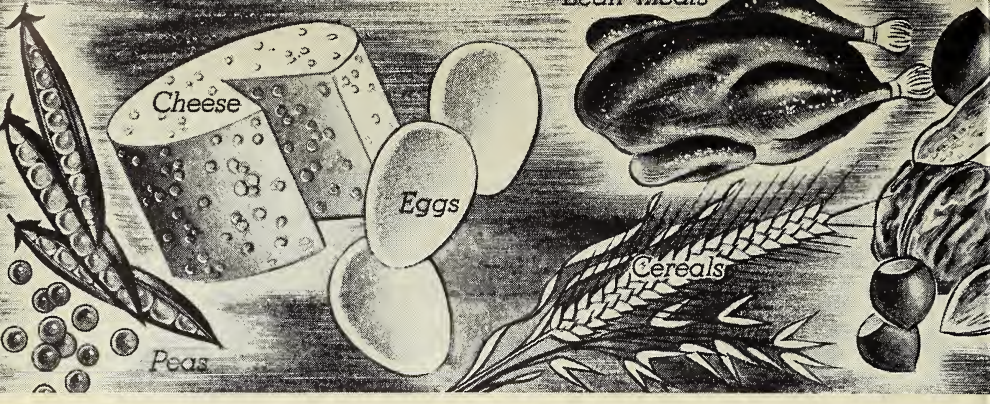
[1] From Henry Clapp Sherman's *Food Products.* By permission of The Macmillan Company, publishers.



These foods are rich in proteins

height, and sex, it would be a mistake to "reduce." Even then it might be a mistake because few children are too fat from overeating. *It is generally better for a growing child to be above the average weight than below it.* Food stored in a young body as fat makes certain that there will be a supply of energy for fighting colds and more serious diseases. No growing girl or boy should try to reduce unless the family physician advises it. It is better to be plump than unhealthy.

The table on page 401 shows the foods that are rich in fat. Many other foods contain lesser amounts of fat (or of oil, which is fat in liquid form). The healthy child should eat some fatty substances every day.

Exercise. How to determine the presence of fat in food: Place the food suspected of containing fat on a piece of unglazed or unoiled paper. If a grease spot is made on the paper, the food contains fat.

The Proteins. Do you remember in our discussion of clover on page 337 that we learned how this plant makes protein with the help of the bacteria on its roots? Other plants and animals make protein in a variety of ways. *Protein, in fact, is the chief substance out of which the bodies of living creatures are built.*

Both plants and animals must have protein for building the cells of their bodies. For that reason, *the protein foods are known as the growth foods.* This complex substance contains nitrogen, carbon, oxygen, and hydrogen, and a little phosphorus and sulfur.

All seeds contain protein. Beans, corn, peas, cereals, and nuts are therefore good sources of supply. Eggs, cheese, milk, and lean meat are all rich in protein. The white of a hen's egg is nearly all protein and water. It is the food that builds the little body of the baby chick before it is hatched.

The table below shows the foods that are rich in protein. Many other foods contain smaller percentages of this valuable substance. Children, whose bodies are growing, natu-

Foods Rich in Protein[1]

	Percentage of Refuse as Purchased	**Percentage in Edible Portion**	
		Protein	*Other Ingredients*
Bacon	8.7	10.5	89.5
Bread (white)		9.2	90.8
Cheese		21.0	79.0
Corn meal		9.2	90.8
Eggs	11.2	13.4	86.6
Fat meat (beef)	1.0	17.75	82.25
Lean meat	19.0	19.2	80.8
Macaroni		13.4	86.6
Navy beans		22.5	77.5
Oatmeal		16.1	83.9
Peanuts	24.5	25.8	74.2
Peas (dried)		24.6	75.4
Rice		8.0	92.0

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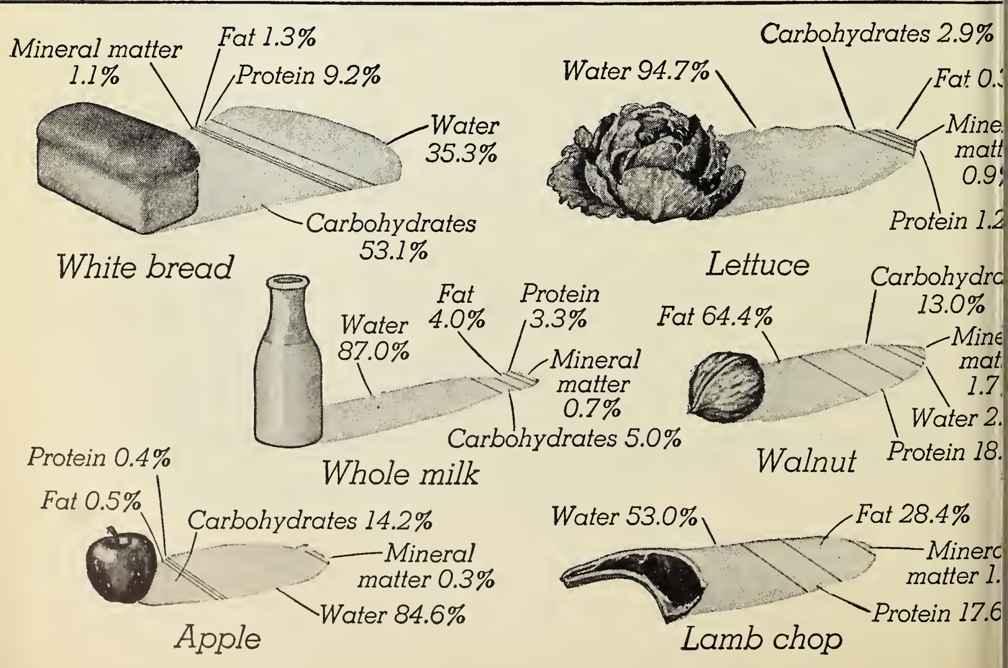
[1] From Henry Clapp Sherman's *Food Products.* By permission of The Macmillan Company, publishers.

rally need more protein than their parents, whose bodies have stopped growing. If you are growing properly and not suffering frequently from indigestion, you can assume that you are getting the proper percentage of protein.

Exercise. How to determine the presence of protein in food: Place a small piece of the white of a hard-boiled egg in a test tube. In another test tube place a small piece of potato. Add a drop or two of nitric acid to each test tube, being extremely careful not to spill any on your body or clothing. The egg white will turn yellow, but the potato will remain white. Next add small amounts of ammonia to each test tube. The yellow color on the egg will change to orange, but the potato will still remain white. This test indicates that the egg white contains protein and that the potato does not.

Most food products are mixtures of carbohydrates, fats, and proteins. Study the diagram below. It will give you the percentages of these three important substances which some of our common foods contain.



Galloway

All living creatures crave salt

OUR NEED FOR MINERAL MATTER

All Creatures Need Mineral Matter. We have seen how plants take mineral materials from the soil and then build them into their bodies. They do this because they need these substances in carrying on the business of living. Animals get mineral materials from the plants and the other animals they eat and from the water they drink. They too need these substances in carrying on the business of living.

We human beings need mineral matter no less than do plants and animals. We need it not only for building healthy bones and blood but also for making our bodies perform in a healthy manner. Let us, then, see what different kinds of minerals we need and why we need them.

Salt. Common table salt is a compound of two elements, sodium and chlorine. With the exception of water, it is the one mineral food that we cannot get entirely from the plant or animal kingdom. We must get it partly from the mineral world, from mines where rock salt is dug out of the earth, or from the evaporation of sea water.

The need for salt in the diet of animals is shown by the risks they take in getting it. In jungles and forests where salt is scarce, animals will travel long distances to visit "salt licks," places where this mineral is found at the surface of the earth. They come for the salt though they know that the human enemy is hiding in the bush.

Exercise. Prepare a feeding station for the birds that live in your neighborhood. Place a handful of salt in it, together with a piece of suet and some sunflower seeds. Do the birds accept or refuse the salt?

Human beings also need salt and will do almost anything to get it if it is scarce. In certain far-off corners of Africa this mineral is prized so highly that a man measures his wealth by the amount of salt he owns. The human body cries for salt not only to bring out the taste of other food but also as a food in its own right. Some salt must always be present in our blood if we are to go on living healthy lives.

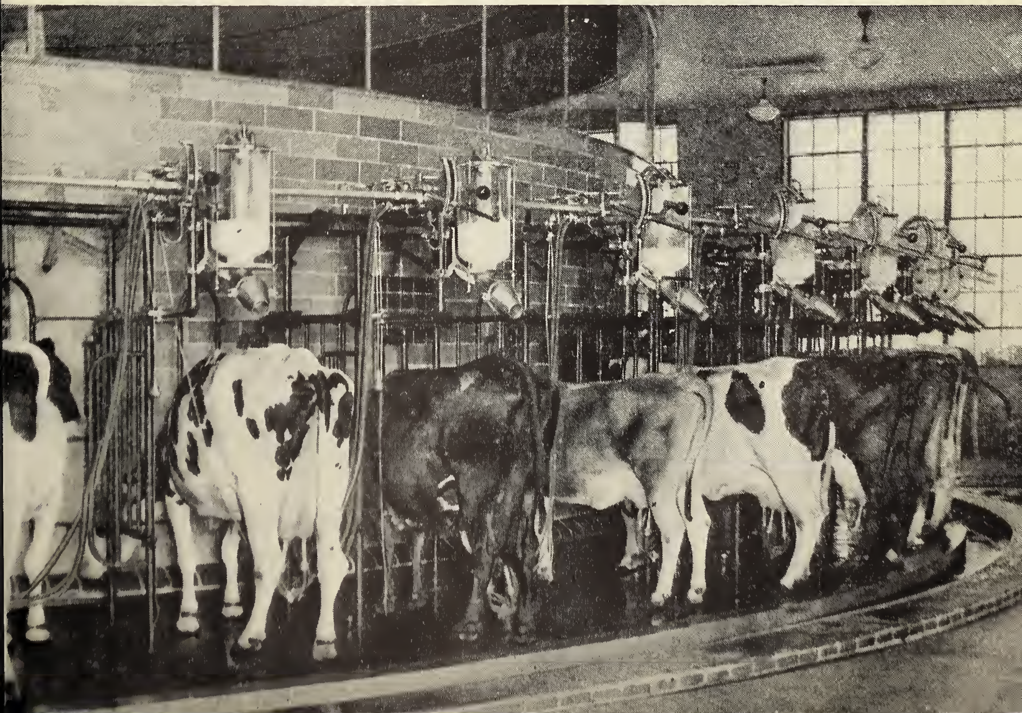
In civilized communities we never need worry about going without salt. It is one of the most abundant and cheapest foods in the modern world. The danger, in fact, is that we may eat too much rather than too little salt. Except when we are losing salt by perspiration during the hot summer months, we do not need to add much salt to our food. Fruits, vegetables, milk, and bread contain some salt, enough or almost enough for our ordinary needs.

Water. Commoner even than salt is ordinary water. We do not generally think of water as a mineral, but it is a mineral and a very important one at that. In Chapter III we saw how every living plant and animal needs water. In the earlier part of this chapter we saw how all our foods contain large percentages of water. We ourselves are made up very largely of this common material. We are constantly losing water through our kidneys, lungs, and skin; so we must constantly replace it with proper food and drink.

Practically all foods contain water. Many fruits and vegetables are almost entirely water. We should eat some of these watery plants every day. We should also drink milk, which contains much water, with our meals, and at least a few glasses of plain water between our meals.

Exercise. How to prove that a food which seems to be dry actually does contain water: Place four or five grains of corn (or beans or any other "dry" food) in a test tube. Heat it and see if steam escapes.

Where much of the calcium for bones and teeth is mined



These foods are rich in mineral matter

Calcium and Phosphorus. Our bones and teeth are made in large part from the element *calcium.* Nothing is, therefore, more important in the diet of a growing child than this mineral material. Though several common foods contain small amounts of this substance, *milk is much the best source of calcium with which to build healthy bones and teeth.* Every child should have liberal quantities of milk or milk products every day. Every child should have as much outdoor sunshine as possible every day, because sunshine helps the body to use the calcium which our food contains.

The element *phosphorus* is also used by our bodies in building our bony skeletons. Phosphorus, however, has many other uses. It feeds our brains and nerves, and it helps the whole body perform its work. Oddly enough, phosphorus when taken from the mineral world is extremely poisonous. When taken from the living world as part of our natural plant and animal food, it is not only harmless but absolutely necessary to health. Milk, cheese, meat, and cereals are good sources of this mineral material.

Iron and Iodine. *Iron* and, to a lesser degree, copper are the elements that make our blood red. By means of iron, oxygen taken from the air is carried by the blood into every part of the body. We therefore can no more live without iron than without air. Liver and spinach are rich sources of iron in the ordinary diet. Other meats and leafy vegetables, as well as eggs and potatoes, contain smaller amounts.

Iodine, like phosphorus, is poisonous when taken directly from the mineral world. When taken from the plant or animal kingdom, it is not only a safe but a necessary part of our diet. Do you remember when studying the water supply on page 101 we learned that in some regions iodine must be added to the water to preserve the health of the people? When iodine is lacking in the diet, a disease called goiter may develop. To guard against this disease we must be sure that our diet contains enough of this mineral material. Fish, oysters, shrimps, and other sea foods are rich in iodine.

How to Get Enough Mineral Food. Fortunately all foods contain some mineral matter. If we vary our foods and eat liberally of milk, fruits, and vegetables, we need not generally be concerned about this important part of our diet. If we develop a taste for raw, baked, or steamed vegetables, so much the better. In boiled vegetables much of the valuable mineral matter goes down the drain with the water.

Exercise. How to prove that food contains mineral matter: Place a grain of corn or a bean in an iron dish or plate, and heat until it has burned to ash. This ash is mineral material.

OUR NEED FOR VITAMINS

The Romance of Vitamins. One of the most romantic chapters in modern science deals with the discovery of those mysterious substances in food which are known as vitamins. Two dreadful diseases, both of which affected sailors more than other people, led to the discovery.

Scurvy. In the fifteenth and sixteenth centuries, when Europeans were vigorously exploring the oceans in all directions, the men who sailed ships were threatened by even greater dangers than the storms and hidden rocks of unknown seas. After they had been on the water for a month or so, a strange weakness would creep over them. Gradually their joints would swell and ache, their gums and noses bleed. Scurvy! It was not unusual in those days for half the crew of a ship to die of this strange disease.

Very early, however, it was suspected that the limited diet of meat and "hardtack" (hard-baked biscuits) might have something to do with scurvy. Late in the sixteenth century a British skipper proved that this was so. He made his crew drink lemon juice and thus cured them of the scurvy! By the end of the eighteenth century the value of lemon juice (and lime juice) in fighting scurvy was so well known that their use was made law on all British ships.

Beriberi. Somewhat later the sailors of the Japanese navy suffered from a different but equally mysterious disease. This beriberi, as they called it, set in like scurvy with a feeling of general weakness. Then the arms and legs of the victims grew numb and in time paralyzed. Late in the eighteenth century about 40 per cent of the sailors in the Japanese navy had been attacked by beriberi. They died like flies in the frost of early winter.

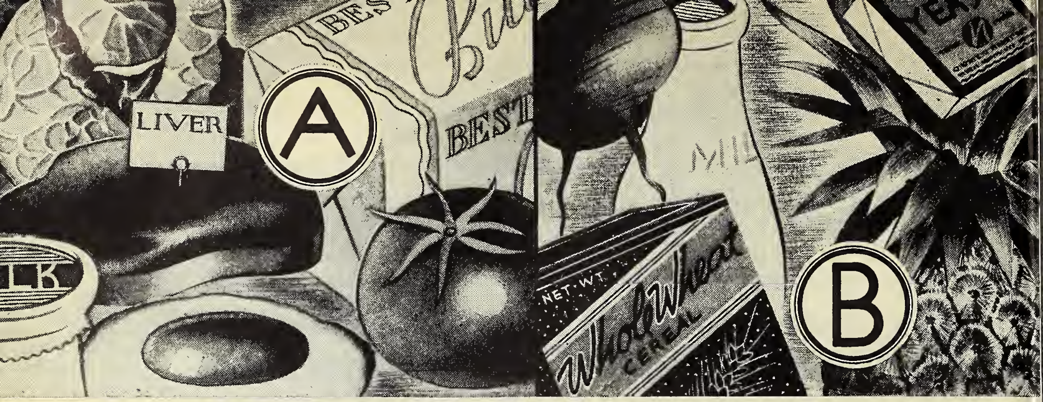
The men that suffered from beriberi, like those that suffered from scurvy, had been eating a very limited diet. Rice, with the husks polished off, was their major item of food. Before the close of the nineteenth century it was noticed that when barley was substituted for some of the rice, the number of cases of beriberi was greatly decreased.

The Discovery of Vitamins. These experiences proved that scurvy and beriberi were caused by an improper diet and that they could be avoided or cured by substituting a proper diet. But what was it that made the diet improper? Was it some germ in salt meat which caused scurvy and which lemon juice destroyed? Was it some poison in polished rice which caused beriberi and which barley destroyed?

Many years of experimentation were required to answer these questions. Not until 1912 did scientists know that scurvy and beriberi were produced neither by germs nor poison. Not until then was it surely known that these and similar diseases were caused *by the absence rather than the presence* of certain substances in the diet.

The substances whose absence caused scurvy, beriberi, and a few other terrible diseases were named vitamins. "Vita" means "life" and refers to the importance of vitamins in the life of both animals and men. The diseases produced by a lack, or deficiency, of vitamins came to be known as *deficiency diseases.*

Since 1912 modern scientists have learned a great deal about vitamins. They have learned that there are several different kinds of vitamins, and that each kind has a job to perform in keeping us healthy. Scientists have also learned that small amounts of each vitamin will work as well as large amounts. A proper diet and plenty of sunshine will supply the amount and variety of vitamins we need. If we observe a few simple precautions in selecting and preparing our food, we need not waste our money on highly advertised vitamin pills in the drugstore.



These foods are rich in vitamins A and B

In spite of all that scientists have learned about vitamins, they have not yet learned exactly how they work. Scientists have learned, however, that *five different vitamins at least are absolutely necessary to health.* They call these vitamins by the simplest scientific terms you will ever have to learn: vitamins A,B,C,D, and G.

Vitamin A. Vitamin A helps us fight a variety of diseases. Not only this, but its absence from the diet brings about serious disorders of the eye. This vitamin is contained in milk, butter, cod-liver oil, egg yolk, liver, sweetbreads, green vegetables, and tomatoes. Foods that have little or no vitamin A are beans, onions, radishes, lean meat, white bread, corn bread, oatmeal, bacon, and molasses.

Do you see how an ignorant person might select a diet that contained not enough of this important vitamin? We need not fear that we shall make this mistake, however, because vitamin A is contained in many common and popular foods. Deficiency diseases caused by a lack of this vitamin are almost unknown in this country.

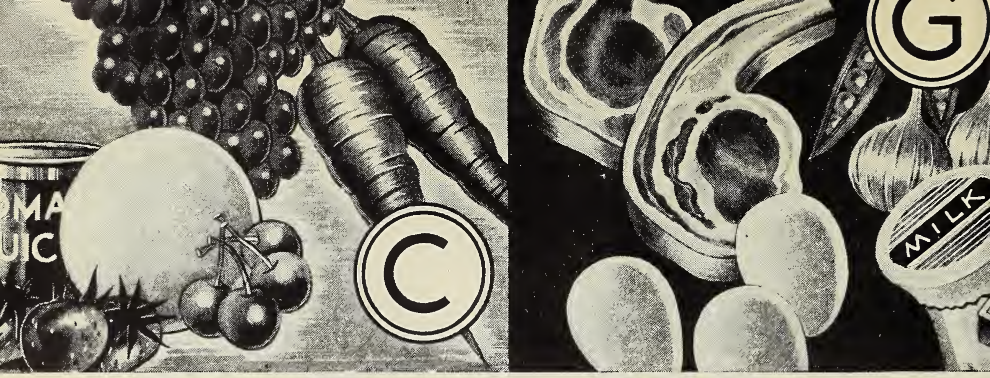
Vitamin B. It is the absence of vitamin B from the diet which causes beriberi. Fortunately vitamin B is abundantly distributed in nature. It is contained in yeast, vegetables, fruits, whole-grained cereals, milk, and meat. Since we in this country eat abundantly of these foods, we are spared the terrible torture of beriberi.

Vitamin C. It is the absence of vitamin C that causes scurvy. This vitamin is present in citrus and other fruits and in vegetables. Unlike vitamins A and B, vitamin C is partially destroyed by cooking. That is why the daily use of grapefruit, oranges, or tomato juice is one of the most healthful habits you can form. Scurvy is still not uncommon among children, but it does not develop if fresh fruits and vegetables are included in the diet.

Vitamin D. Deficiency of vitamin D is the cause of rickets, a disease from which a great many children today are suffering. In experiments with animals it has been shown that the body of the animal suffering from rickets does not properly make use of the calcium and phosphorus in its food, elements which are needed for the development of teeth and bones. Bowlegs, knock-knees, and many other deformities of the skeleton are the result.

Rickets may be avoided or cured by the use of foods that contain vitamin D. Unfortunately this vitamin is not present in many foods, but it is abundantly present in cod-

This is the way to build strong bones



These foods are rich in vitamins C and G

liver and halibut-liver oil. It is also manufactured in our bodies by sunlight. Rickets is not likely to develop in children who play outdoors in the sunshine. It is chiefly for children in crowded cities, and in places where winter brings many dark days, that a substitute for sunshine must be provided. The best-known substitute for play in the sunshine is cod-liver oil.

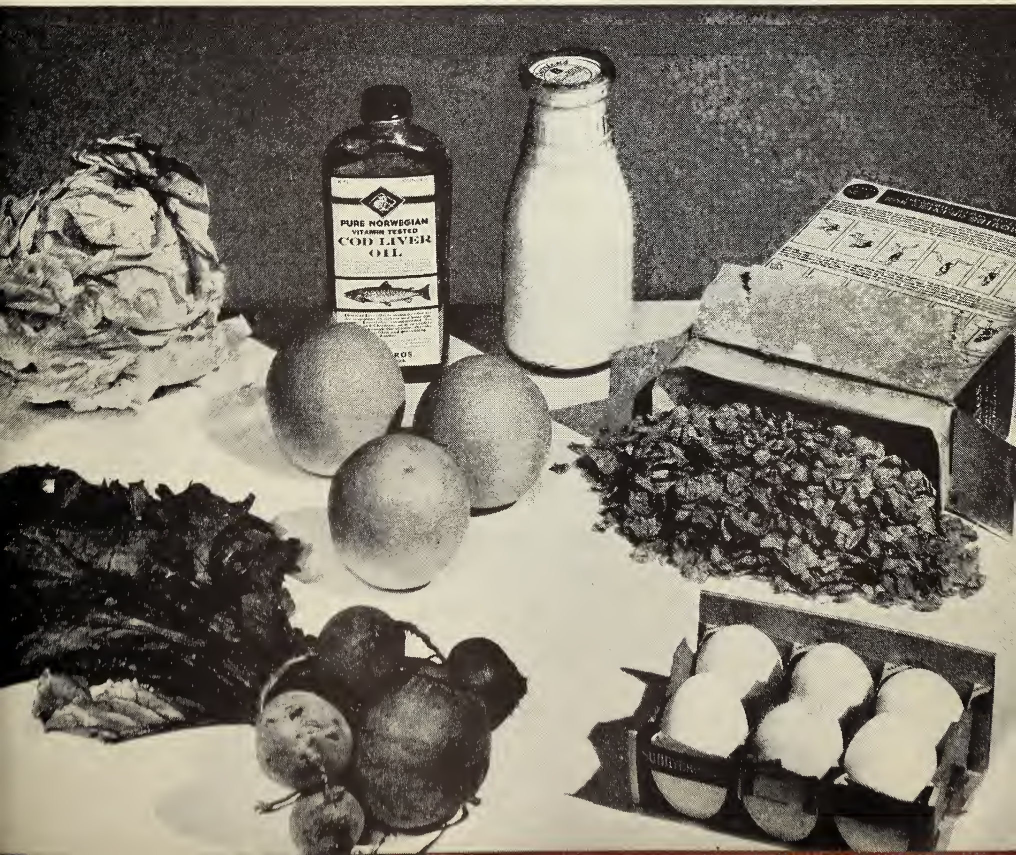
Vitamin G. A deficiency skin disease known as pellagra is caused by a lack of vitamin G. Pellagra is common among people who do not have certain types of food. In one section of the country where this distressing disorder was common, it was found that the main articles of food used by the sufferers were white flour, corn meal, polished rice, fat pork, and molasses. Experimental work has shown that these foods are deficient in vitamin G. It has shown that the cure for pellagra is fresh meat, milk, yeast, eggs, and fresh vegetables, foods that are rich in vitamin G.

How to Get the Vitamins We Need. All important vitamins, then, except vitamin D are widely present in our common foods. The illustration on the opposite page pictures some well-known foods which are rich in the different vitamins. *Of all our foods, green vegetables and fresh fruits* *are the richest in vitamins.* A diet of fresh vegetables, fruit, milk, milk products, meat, and whole-grained cereals will take care of our vitamin needs. Add sunshine (and subtract some of the cake, pie, candy, and other confections if these are crowding more healthful foods from your diet) and you need have no fear of any deficiency disease.

The Balanced Diet. A diet which contains the proper proportions of carbohydrates, fats, proteins, minerals, and vitamins is said to be *balanced*. A good cook prepares meals that are balanced as well as tasty. She includes enough energy foods to meet the needs of the active children in the family. She provides enough growth foods to build firm and sturdy bodies. She serves fruits and vegetables

Can you name the vitamins that each of these foods contains?

Galloway



every day for the minerals and vitamins they contain. She serves simple desserts more often than rich ones.

Exercise. Make a list of foods for a well-balanced dinner. List the foods under the following heads: "Energy Foods," "Growth Foods," "Mineral Foods," and "Vitamin Foods." You may list the same food under more than one head. Use the tables given in this chapter to help you to plan the dinner.

Our Fourth Exploration. In this chapter, our fourth exploration in the living world, we have chiefly considered ourselves. We have seen how all the rest of the living world provides food for us. We have also seen how science helps us select such foods as will make us happy and healthy.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. With the exception of the brain, man's body is not superior in any way to the body of a horse.

2. Most of the food we eat comes from a region within a few miles of home.

3. Thousands of people in the United States die every year from eating spoiled or impure food.

4. Like animals, we can trust our appetites to lead us to a proper diet.

5. Growing children should eat plenty of the energy-giving protein foods.

6. All meats are rich in starch.

7. Fat is the only kind of food that is stored in the body for future use.

8. Milk is a good food for babies but not for school children.

9. We need not drink water because we get all the water we need in our food.

10. Scurvy is a disease which is produced through an absence of vitamin A in the diet.

11. It is never necessary to add cod-liver oil to the diet because vitamin D is abundant in many common foods.

12. A balanced diet is one in which the carbohydrates equal the proteins.

Questions for Discussion

1. Would it be possible for a person to eat large quantities of food and still in a sense starve to death? Explain exactly how.

2. What differences would you recommend between the diet of a bricklayer and that of a bank cashier? between the diet of an Eskimo and that of a native of the Congo? between the diet of a family in the winter and that of the same family in the summer?

Things to Do

1. Keep a record of the meals you eat during a week and list the countries from which the various foods come. Get an outline map of the world and show the places where the foods listed came from.

2. Investigate and report on the care and preservation of foods (*a*) in stores; (*b*) in the home.

3. Plan a well-balanced diet for your family for a week. Ask your mother if she will let you plan at least one meal which she will really prepare for the family.

4. If you have a cafeteria in your school, prepare a list of recommended food combinations to be placed on the walls of the cafeteria. One large school has such a chart, which is labeled "For a well-balanced meal select one dish from each of the following groups." For the benefit of the smaller children the various recommended dishes are pictured. Find out what your school cafeteria is serving throughout the week and prepare a chart of its dishes. You might all work together on this, with some members of the class preparing the chart, some others printing the chart, and still others painting the pictures.

5. Make a list of the different food substances found in milk. Pretend that you work for a large milk company. Write a good advertisement for milk or make a good poster.

6. Read Paul de Kruif's *Hunger Fighters*. This will tell you in a very exciting way how the vitamins were discovered.

UNIT SIX

THE WORLD OF ACTION

NC 18100

EXPLORING
THE WORLD OF ACTION

◆

We have now explored the worlds of water, air, rock, and living creatures.

Is this all there is on earth to explore?

◆

The answer is No.

There is one other world in the world around us.

In one way it is the most important world of all because it helps unite all the other worlds into one great world of worlds.

It is a mysterious world, which not one of us can see but which all of us must deal with every minute of our lives.

◆

What is this world?

How is it related to the other worlds?

How is it related to us?

These are not easy questions to answer, but Unit Six is going to try.

◆

CHAPTER SIXTEEN

What Is Energy and How Do We Use It?

THE FORCE OF GRAVITY

The World around Us Is Always Changing. In studying the different worlds which unite to form the great world in which we live, we learned that water, air, rock, and living creatures are different in many ways. In one way, however, they are all the same. Something is always being done to them so that they are forever being changed.

We saw, for example, how water is forever changing its form from liquid to gaseous, from liquid to solid, and then back to liquid again. We saw how air is forever changing back and forth from warm to cool, from light to heavy, and from here to there. We saw how rock material never rests in its journey from the highlands to the sea and then back to the highlands again. We saw how all plants and animals are busy with the endless job of eating, self-protection, and reproduction. We saw, in short, that not one of the worlds we have studied is long idle, that not one remains long unchanged.

What Energy Is. There is something in all these worlds which keeps them forever on the move, which gives them the ability to be active. We call this something energy. We ourselves use energy when we push or pull or lift an object and when we move from one place to another. *We may define energy simply as that which makes material things move their position or change their form.* Nobody can see energy; nobody can say exactly what it is. But we can know what energy does.

What Energy Does. Energy makes possible many different kinds of action. There is, for example, the energy in our muscles with which we walk, throw baseballs, kick footballs, and do many other things. There is the energy of the wind which we can harness to windmills for pumping water out of the ground. There is the energy of flowing water which runs our mills, and the energy of steam which runs our locomotives. There is also the mysterious energy of heat which, when unloosed from gasoline, can be made to run our automobiles. There is the even more mysterious energy of electricity which can be carried in wires no thicker than the lead of a pencil and which yet has the strength of a thousand men.

Energy is always at work in the world around us. It makes all things behave as they do. Energy, however, is different from anything else in the world. It really makes up a world of its own, the fascinating world of action. But before we can understand energy we must understand force and particularly the force of gravity.

Why Objects Fall. It may seem strange, but it is a fact, that nobody knows exactly why objects fall toward the earth rather than away from

The force of gravity is pulling this man toward the center of the earth

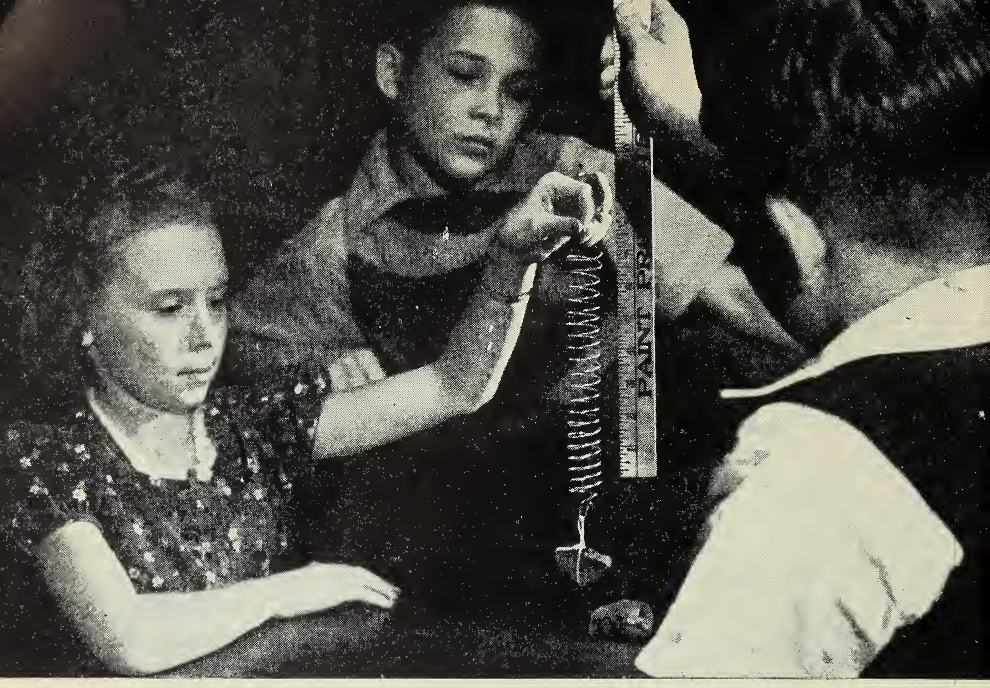
Acme

it. We only know that something which we call a "force" exerts a constant pull between the earth and objects which are on or near the surface of the earth. *This force, or pull, is known as gravity.* The word "gravity" means "heaviness." To say that a thing is heavy is just another way of saying that there is an attraction between it and the earth.

All objects on the surface of the earth are pulled by the mysterious force of gravity toward the center of the earth. Not only that, but *any two objects, no matter what their size or where they are in the universe, pull at one another in exactly the same way.* The heavier the object, the greater is its power to pull at some other object. The pull of two objects which weigh fifty pounds apiece is extremely slight, but it can be measured by special instruments. The pull of larger objects on one another, such as that which is exerted between the sun and the earth, is very great.

What Weight Is. The attraction between the earth and objects on its surface is always the same in any given place. This fact makes it possible to measure the force of gravity and to use the measurements for many practical purposes of everyday life. All of us must deal with this force every minute of our lives. It is therefore only natural that methods of measuring it were among the earliest inventions of the human mind.

Exercise. How to determine the difference between a "light" and a "heavy" object: Get a coiled spring from the inside of a broken window-shade roller or from a garage man or a dealer in junk. Measure the length of the unstretched spring. Fasten a light object, such as a small stone, to one end of the spring, as shown on page 426, and measure the length of the spring again. How much does the light object stretch the spring? Next fasten a heavy



These children are measuring the force of gravity

object, such as a fairly large stone, to the end of the spring and measure the length of the stretched spring. Which object stretches the spring to a greater extent, and how great is the difference in inches?

By this very simple experiment you measured a force which is not simple at all. You measured the pull of gravity on two objects which respond to the pull differently. You found that the pull was greater on the object which you called heavy than on the object which you called light. You measured the pull on each object by the inches through which the spring was stretched. In the same way you measured in inches the difference in the pull on the two objects.

In other words, you weighed the two objects. *Weight is merely the name we give to the measurement of the pull which exists between the earth and an object at the surface of the earth.* Weight is therefore a measure of the force of gravity. Though springs are commonly used for weighing things, weight is not generally recorded in inches.

The photograph below shows a common type of *spring scales* which is used for weighing things. Notice that a pointer is attached to the coiled spring. When the spring is stretched the pointer moves down along the face of a scale, which is marked in the same way a thermometer is marked. On the thermometer, you will remember, the little marks are called degrees, and they are used to measure temperature. On the spring scales the little marks are called pounds and ounces, and they are used to measure weight.

The Units of Weight. Long ago men agreed to call certain pieces of metal of different weights by different names. One of these pieces of metal was called a *pound.* When this pound weight of metal—or some other piece of metal of exactly the same weight—is hung from a spring, the spring stretches a certain definite distance.

This man is measuring the force of gravity in terms of pounds and ounces

Any other object that causes the spring to stretch the same distance must weigh the same amount, that is, one pound. Any object that causes the spring to stretch twice as much weighs two pounds. Do you see, then, how the pound is a unit of weight which can be widely used to measure the pull of gravity between the earth and a wide variety of articles?

No doubt you have struggled with tables of weight in arithmetic. You may not remember the tables, but you will certainly remember that there are many different units of weight. Not only this, but the same names may be used in different tables for very different units of weight. Even the pound is not the same weight in all the different tables. In one table the pound is divided into 16 ounces. In another it is divided into 12 ounces.

Do we have these different tables merely to make the units of weight more difficult to understand? The answer, of course, is No. We have different units of weight to meet the needs of different people. The druggist, who must weigh very small amounts of medicine very carefully, could hardly use our ordinary pounds and ounces. These common units are useful in weighing potatoes but useless in weighing pills. The druggist needs much smaller units of weight than pounds and ounces and much more sensitive scales than the grocer uses. In the same way, the jeweler could hardly use pounds and ounces for weighing precious gems. Like the druggist, he needs his own units of weight to fit the materials with which he works.

What Gravity Does. The force which we call gravity does more than give objects on the surface of the earth enough weight to keep them from flying off into space. Gravity is also the force that gives water the energy of motion which

Black Box Studios

ensitive scales and light weights are needed for weighing small quantities of materials

makes it run downhill. Rain falling on the highlands rushes to the lowlands and the sea because gravity pulls it down. In doing so, water power (which we studied in Chapter VI) is developed. Thus *the force of gravity brings about the energy of running water, which in turn has become a valuable servant of man.*

Gravity has helped us in other ways. Human life requires a great deal of lifting and moving of objects—whether it be merely to lift ourselves out of bed or to move thousands of tons of steel in building a skyscraper. Gravity, which pulls on everything, makes lifting and moving difficult. Because of this, man has had to discover and invent ways of fighting the force of gravity, and in doing so he has learned to use energy. Thus *gravity has been a spur to the human power of discovery and invention.*

Exercise. If men lived on the moon instead of the earth, do you think they would have more trouble or less trouble lifting and moving things?

What are some of the forms of energy which men have harnessed in their fight against the force of gravity? Let us see.

THE ENERGY OF MOTION

What Starts an Object Moving. It is easy to see that objects at rest do not start moving by themselves. Some push or pull, which we call "force," is needed to get them going. A man, for example, can move an automobile over the cement floor of a garage without help from the engine, but he must push very hard to get it started. Once the automobile is rolling, however, the man does not have to push so hard to keep it rolling.

Objects at rest tend to remain at rest. The push or pull which is necessary to start objects moving on the surface of the earth suggests that objects at rest tend to remain at rest. A few simple experiments will clearly show you that this is true.

Exercise. Place a piece of paper on top of your desk and a paperweight on top of the paper. Take hold of one end of the paper and give it a quick jerk. Does the weight tend to move or to stay still when you jerk the paper out from under it? Pile four or five books on the desk. Quickly jerk out the bottom book. Do the books on top tend to move or to remain where they are?

Have you ever been thrown backward in an automobile when the automobile suddenly moved forward? If you have, do you see why?

Moving Objects Tend to Go on Moving. We saw above that after a man pushes an automobile until it starts rolling, he can easily keep it rolling. This is because all moving objects tend to go on moving.

Exercise. Place a ball in a chalk box or in a cigar box from which one end has been broken away, as shown below. Push the box along the top of the table rapidly and then stop it quickly. Does the ball in the box tend to stop or to go on moving?

There are many common happenings that illustrate this tendency of objects in motion to keep going. When the brakes of a moving automobile are suddenly put on, the passengers are thrown forward. In a collision, they may be thrown against or even through the windshield.

This boy is proving that moving objects tend to go on moving

Friction. Once an object starts moving, what is it that makes it stop? The answer is that there are many forces which stop the motions of objects on the earth. Most important is the force of friction. This is the resistance, or drag, which is brought about when two surfaces are rubbed together. You probably know about friction between sandpaper and wood, between a tire and the road, between two parts in a machine, between a nail and the board into which it is being driven. You may have had experience with friction in sliding down a banister or down a hill on which the snow had worn thin. If so, you know that *the smoother the surface, the less friction there will be between the surface and an object moving over it.*

How We Make Use of Friction. The proper use of friction is absolutely necessary in driving an automobile. You must have tires which are not smooth in order to produce enough friction between the tire and the road to keep from skidding. You must have good brakes so that when the brakes are set the friction between the brake lining and the brake drum is great enough to stop the wheels.

The faster a car is moving, the greater is its tendency to continue to move. If it is moving slowly, it will move only a very short distance after the brakes are set. Tests have shown that a wide-awake driver with good tires and brakes can stop a car moving at 20 miles an hour at about 52 feet from the point where he first steps on the brake. If the car is moving 50 miles an hour, it will move 243 feet after the brakes are first put on.

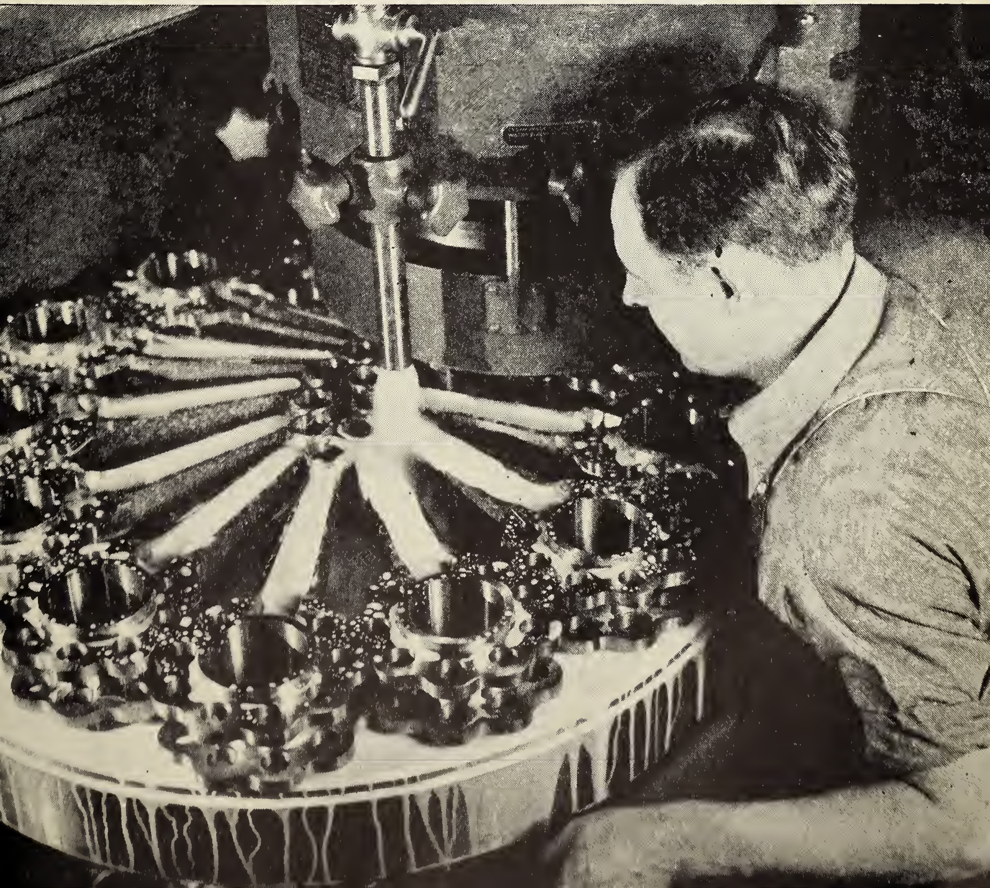
How We Reduce Friction. The engine of an automobile, on the other hand, must always be kept well oiled so that its moving surfaces are smooth. In this way friction is reduced and movement goes on more easily. Many other kinds of machinery must be oiled for the same reason.

A great deal of force is required to drag a log over dry earth. Much less force is required if the log is loaded on a wagon, because there is much less friction when it is moved on wheels. Some wheels are set with ball bearings, which further reduce the friction. In one way or another all machinery which contains moving parts must be built so that friction will be reduced as much as possible because *friction opposes motion.*

Motion at Work. Everywhere we go in the modern world we see the energy of motion at work. We see it in ourselves

Oil is used to reduce friction in moving machinery

Robert Yarnall Richie



when we walk, run, and breathe. We see it in automobiles, trains, and airplanes. We see it in factories and power plants. We sometimes speak of our time as the Machine Age because in no other age have men made machines do so many different kinds of work. A great many of these machines work with the energy of motion.

Motion, however, is not the only kind of energy. Let us next examine heat, which is another kind of energy.

THE ENERGY OF HEAT

The Sun Is the Source of Energy. Scientists tell us that the sun is nearly ninety-three million miles away from the earth. One might think that anything so far away could have very little influence on our lives. The fact is, however, that every minute of our lives we use energy which came from the sun. It comes to us in the rays of the sun as radiant energy. On the earth radiant energy may be changed into many different forms. One of these forms is heat.

Though heat is one of the most important types of energy, it might not at first thought seem to be energy at all. But if we think over the various explorations we have made in the world around us, we realize that heat was behind many of the things we saw happening there.

Do you remember our study of the water cycle on page 86? The water that is constantly evaporating from the surface of the earth and rising into the air is being driven by the heat energy of the sun. Without this heat there would be no evaporation, and without evaporation there would be no rain and running water. *Because the heat of the sun provides the water which gravity drags from the highlands to the lowlands, it must be given some of the credit for the power of running water.*

This pavement was warped by the heat of the summer sun

Do you remember our study of wind on page 172? We found that the winds blow because parts of the air at the surface of the earth become more highly heated than other parts. So *when we make the wind turn a windmill or move a sailing vessel, we are using energy which came in the first place from the sun in the form of heat.*

Do you remember that plants take their food directly from the water, the air, and the soil? Do you remember that they can do this only because sunlight changes the water and carbon dioxide into sugar? We learned that all living creatures, both plants and animals, depend on this ability of plants to manufacture sugar. All the food we eat, whether animal or vegetable, is therefore made possible by the sun. All our activities, on the other hand, are made possible by the food we eat. Do you see, then, that *all our* *activities are made possible through energy which came in the first place from the sun?*

The energy of running water, wind, and food are only a few of many different types of energy which comes from the sun chiefly in the form of heat. We shall learn about certain other types as we go deeper into this chapter.

Heated Objects Expand. In studying the thermometer on page 76 we learned that most things get larger (expand) when heated and smaller (contract) when cooled. We have

The level of this bridge is about eight feet lower in summer than in winter because of the lengthening and shortening of the cables by heat and cold

already studied several examples of this sort of expansion and contraction. Other examples may be seen almost anywhere we go.

Have you ever seen sidewalks or streets that have risen, or buckled, with the heat of a summer day? If not, look at the picture on page 435. In the same way telephone and telegraph wires stretch and sag with the heat in summer. A copper wire a mile long may be as much as four feet longer on a hot day than on a cold day!

Study the photograph on the opposite page which shows the George Washington Bridge over the Hudson River. The steel cables that support this bridge are almost a mile long. The lengthening and shortening of these cables by heat and cold make the level of the bridge about eight feet higher in winter than in summer. Do you see how the energy of heat is able to perform gigantic tasks?

Nearly all materials—solids, liquids, and gases—expand when heated. A few simple experiments will show you how these different kinds of materials act when heated.

Exercises. How to prove that solids expand when heated: Perform the so-called ball-and-ring experiment. The necessary pieces of equipment are shown on page 438. The metal ball should just be able to pass through the metal ring when both are cold. Heat the ball and try to pass it through the ring. What happens? Let the ball cool. Heat the ring and try to pass the ball through. What happens now? Let the ring cool. Heat both the ball and the ring and again try to pass the ball through. What happens?

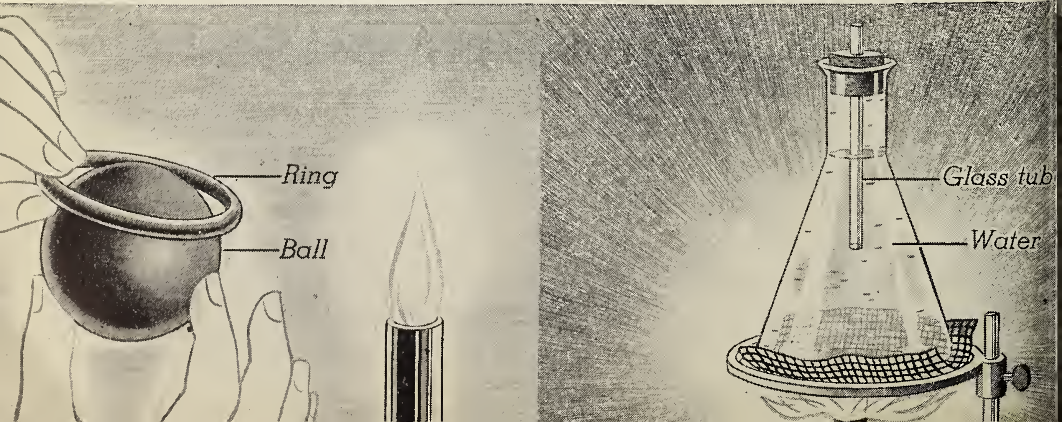
How to prove that water expands when heated: Fill a glass flask with cold water. Put in a stopper with a hole in it through which there is a glass tube as shown on page 438. Now turn a gas flame against the flask, and the water will expand. It will probably expand until it flows out the end of the tube. After the flame is taken away, what happens? Why?

How to prove that air expands when heated: Fasten a sheet of rubber over the mouth of a dry flask, as shown on the opposite page. Apply heat to the flask. What happens? What does it prove?

How Heated Materials Perform Work. Materials that expand when heated release energy which men have harnessed for a great variety of work. To describe all the ways of using this energy would make a book a great many times longer than this one. One material, however, is used much more than any other in harnessing the energy of heat for useful work. That material is water in the form of steam.

Exercise. How to show the way steam performs work: Put about an inch of water in a test tube and plug with a rubber stopper which you have first greased with vaseline. Put the test tube in a holder and then hold over a flame, as shown on the opposite page. Two precautions are necessary in this experiment: (1) do not put the stopper into the test tube very tightly, and (2) be sure to point the top of the test tube away from yourself and your companions. What happens when steam forms beneath the stopper? Where does the energy responsible for what happens come from?

These experiments prove that both solids and liquids expand when heated

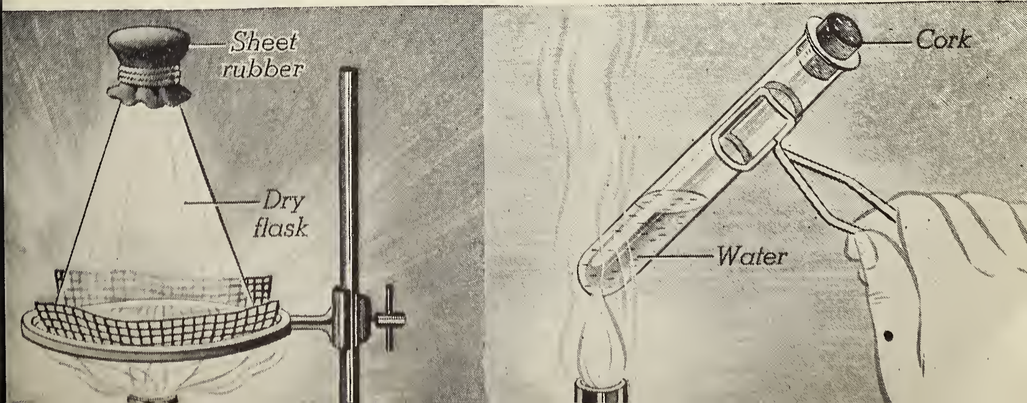


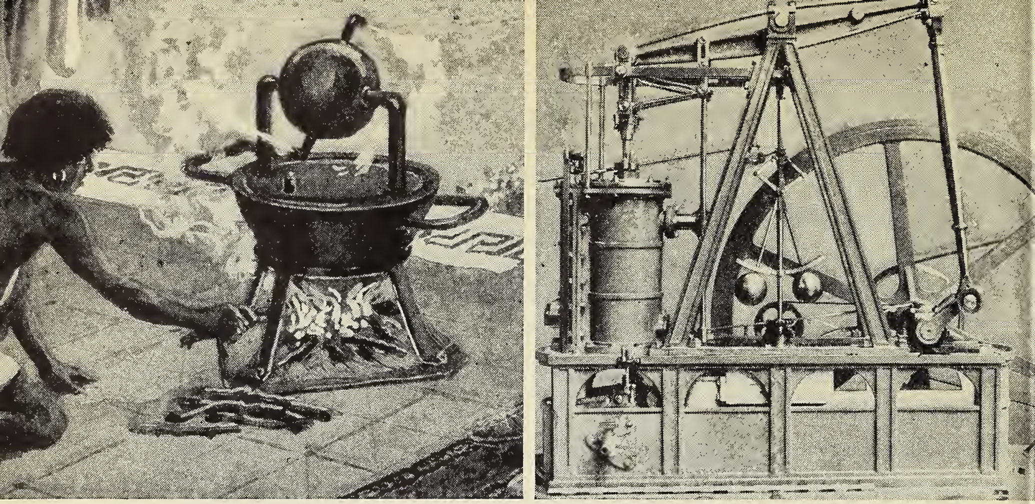
The tremendous energy of steam was known to men over two thousand years ago. Long before the birth of Christ a Greek by the name of Hero invented a machine for putting this energy to work. The illustration on page 440 shows Hero's "ball of the winds." Notice that the ball has a pair of hollow arms on either side which are bent in opposite directions.

When Hero partly filled the ball with water and kindled a fire beneath it, steam poured out of the hollow arms. The pressure of the steam against the outside air made the ball spin round and round. The "ball of the winds" worked in the manner of a modern spinning lawn-sprinkler, excepting, of course, that the lawn-sprinkler is driven by liquid water rather than by steam.

Hero's steam engine was only a toy, but men were bound to realize sooner or later that steam could be made to do useful as well as useless work. Not until 1769, however, was a really practical steam engine invented. In that year a Scottish inventor, James Watt, patented the steam engine pictured on page 440. Notice the *cylinder* in which the steam is trapped, the *piston* which the steam *pushes* up and down, and the *wheel* which the moving piston turns. Watt's engine was strong enough to run a great many different kinds of machinery. It was the grandparent of all modern steam engines.

These experiments prove (1) that air expands when heated and
(2) that steam can be made to work





Compton's Pictured Encyclopedia

The energy of steam was used as a plaything nearly two thousand years before it was used to do useful work

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Buried Sunshine. Steam power was less widely used than liquid water power for several years after Watt's great invention. But with the invention of better and better machines for harnessing it, the energy of steam came more and more into use. *Today much the greatest amount of power used in factories comes from steam.*

Do you see, then, that the heat which produces steam plays a very important part in modern life? This heat comes from the sun in a way which is truly marvelous. We all know that even in the tropics the direct rays of the sun are not hot enough to boil water and produce steam. Fortunately for modern men, the energy from sunshine of past ages has been stored in coal and oil and buried in the earth. *The earth is a bank whose underground vaults contain some of the greatest wealth in the world.*

Coal. When you burn a piece of wood, you are really releasing the stored-up energy that came from the sun. Wood is produced only through sunshine acting on the green leaves of plants.

Long ages ago great swamps, like the one shown below, covered large parts of the land areas of the globe. Strange trees lived and died in these swamps. As the dead plants piled up, bacteria feasted; but they drew more heavily on the oxygen and hydrogen than on the carbon of the decaying vegetation. The result was that part of the carbon piled up and became buried under sand and mud.

With later ages the imprisoned plant remains were squeezed together and hardened into the substance which is known as coal. Being rich in carbon, coal is rich in energy that can be released by burning. *It is the most valuable source of heat energy in the world today.*

Exercise. Examine some coal and see if you can find the form or pattern of plants pressed into it. These prints are fairly common on soft coal, but they have rather generally been destroyed in hard coal by movements of the rocks.

hese dead trees in the Dismal Swamp of Virginia recall the events of a far-off time when other trees in other swamps were turned into coal

Galloway

Petroleum. Products of plant and animal decay which are rich in carbon have been stored in the earth in liquid and gaseous as well as solid form. *The liquid form of these products is called petroleum; the gaseous form, natural gas.* Petroleum and natural gas were formed in many past ages much as coal was formed. Like coal, they are rich in energy which can be released by burning.

As a source of energy petroleum has already outstripped running water, and it is rapidly outstripping coal. Modern ships, to mention but one example, use petroleum in preference to coal as a source of heat for their boilers. Furthermore, *the invention of the gasoline engine made it possible to use the energy of petroleum without changing it first into steam.* Gasoline, a product of petroleum, is perhaps the most convenient source of energy in the world.

THE ENERGY OF ELECTRICITY

The Youngest Giant of Industry. Running water, coal, and oil are giants which have done, and still do, a great deal of work in the modern world. Another giant has more recently come to help them, a giant which in some ways is the most marvelous and mysterious of all. This giant is electricity.

Ancient Knowledge of Electricity. Nobody knows exactly when it was that men first discovered the strange thing which today is known as electricity. It is certain that sev-

The remains of plants are commonly preserved on soft coal as well as on the rocks in which the coal is mined

A. M. N. H.

eral centuries before the birth of Christ, the Greeks knew something about it. They knew that if amber was rubbed, it would gain the ability to pick up small pieces of paper or other light objects. They called amber *elektron.* Our word *electricity* comes from this old Greek word. We use the word "electricity" to apply to the strange energy which nobody can define but which anybody can produce merely by rubbing a piece of amber.

Other materials are almost as good sources of electricity as amber. Who has not drawn sparks of electricity by scraping the feet on a rug and then touching some object in the room? By doing this you "charge" your body with electricity through rubbing, just as the Greeks charged amber.

Exercise. Rub a comb or a fountain pen vigorously with a piece of flannel and then hold it near some small bits of paper. How long after rubbing do the hard-rubber objects have power to attract the paper?

Magnetism. Probably long before the Greeks learned about the electrical power of rubbed amber, other ancient peoples knew that a certain kind of iron compound had the power to attract other small pieces of iron. This peculiar substance was named magnetite, a word from which we get our modern word *magnet.*

Ancient peoples also knew that if a piece of magnetite were floated in water on a piece of wood it would always tend to point in a north-south direction. For this reason pieces of magnetite came to be known as loadstones ("leading stones") because they had the ability to lead one in a north-south direction.

It is easy to see how the knowledge of loadstones led to the invention of the *compass.* It is less easy to see why other uses for the power of magnets were not discovered long ago. The fact is, however, that except in the compass this power was put to no practical use until the early years of the last century. The giant, electricity, lay idle at least twenty-five hundred years after it was first discovered!

The Harnessing of Electricity. Not until the nineteenth century did men learn that electric energy could be developed in several different ways; that it could be carried from one place to another through wires and made to do a great variety of work.

Today we live in an age of electricity. This marvelous form of energy lights our houses, runs our pumps and vacuum cleaners, toasts our bread, rings our doorbells, cools our food, keeps us in touch with far places through the telephone and the telegraph, and entertains us with the radio.

Outside our homes electric energy lights our cities, runs our streetcars, elevated and subway trains, helps to run our automobiles by firing the gas in their cylinders, lifts elevators, and turns the wheels of countless industries. How can electric energy do so many different things? The answer is that (*1*) *electric energy is easy to produce and control, and* (*2*) *it can be easily changed into other forms of energy, such as light, heat, and motion.*

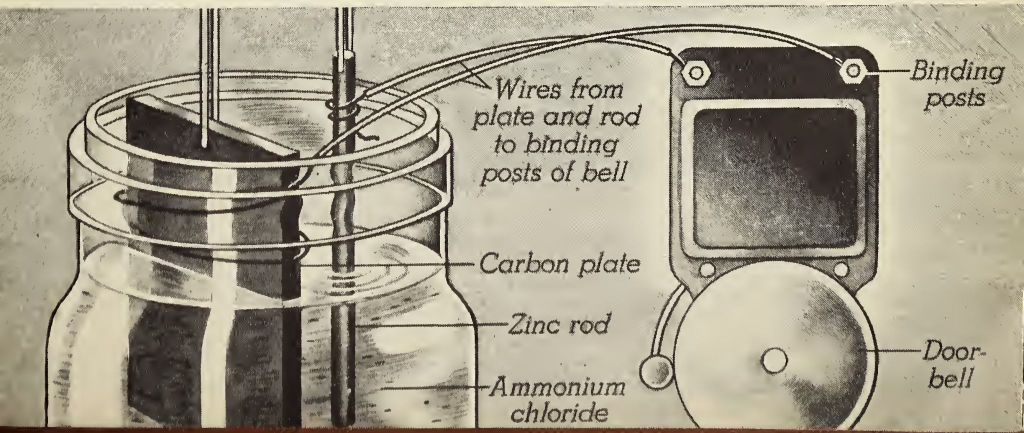
Electricity in Motion. The harnessing of electricity could not really begin until someone discovered that electric energy could be made to flow in a steady current from one place to another. The electricity which you store in your body when you scrape your feet on the rug is at rest. When you touch an object, you discharge it suddenly in a spark. Such resting electric energy, which spends itself so suddenly, cannot be made to do any useful work.

Alessandro Volta (1745–1827), an Italian scientist, was the first person to show that electric energy could be produced in a steady current through chemical activity. He paved the way for all future development of electric power. The *volt*, a unit which is used today for measuring that energy, honors Volta for his great discovery. By a simple experiment you can follow in Volta's footsteps and produce an electric current.

Exercise. How to make a "wet cell" electric battery: Obtain from a dealer in electrical supplies a carbon plate and a zinc rod, as shown in the illustration below. Nearly fill a quart fruit jar with water in which as much ammonium chloride as the water will absorb has been dissolved. Hang the carbon plate and the zinc rod in the solution, but do not let them touch one another. Attach copper wires to the ends of the plate and the rod. If these wires are connected with an ordinary electric doorbell, the bell will ring.

The reason why the wet cell in the above experiment can ring a bell is that a steady current of electric energy is produced by certain changes in the cell. This current flows steadily out of the cell and into the bell through wires, and then back into the cell again. Inside the bell the electric energy is turned into the vibrating motion of the clapper which makes the sound.

Here is how you may produce a steady electric current

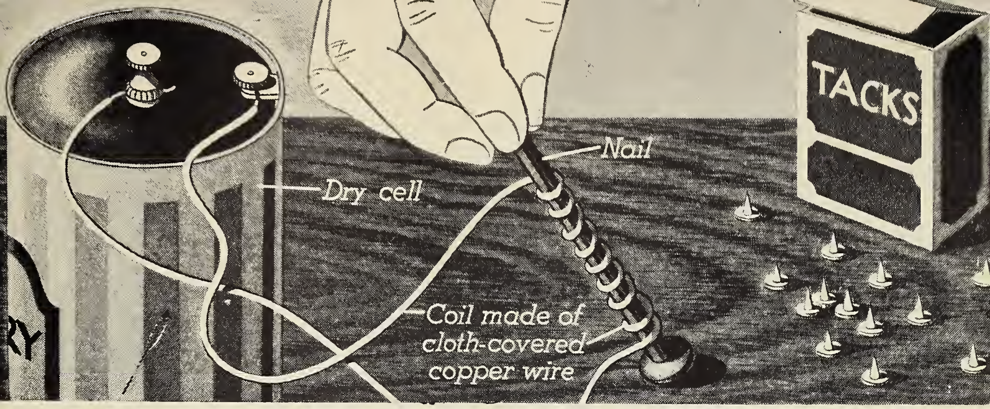


Turning Electric Energy into Motion. How is the electric energy of the cell turned into the energy of motion which rings the bell? Before we can answer that question we must return to the subject of magnetism. We have seen how the people of ancient times knew that a certain kind of iron had the power to attract other pieces of iron. It was not until many centuries later that this fact was put into practical use. Magnetism did not become a useful tool of man until scientists discovered that any kind of iron could be made into a magnet with the help of an electric current. Such a magnet is called on *electromagnet*.

Exercise. How to make an electromagnet: Wind a coil of cloth-covered copper wire tightly round an iron nail or spike, as shown on the opposite page. Connect the ends of the coil with an electric battery. Place some carpet tacks near the nail. What happens?

Do you see how easy it is to make a magnet out of any piece of iron that happens to be handy? Do you see how easy it is to turn the magnetism on and off merely by turning the electric current on and off? Not only the electric bell but the *telephone*, the *telegraph*, the *electric motor*, and many other machines use electromagnets for changing electric energy into motion. Later in your study of science you will probably experiment with some of these machines and learn exactly how electromagnets make them go.

Turning Electric Energy into Heat and Light. Electricity passes much more easily through some materials than others. We call these substances through which it flows easily good *conductors*. Silver is the best-known conductor of electricity, but copper is the best *cheap* conductor. That is why electric wires are generally made of copper.


TACKS
Nail
Dry cell
Coil made of cloth-covered copper wire

Here is how you may make a simple electromagnet

Certain materials greatly resist the flow of an electric current and in doing so turn the electric energy into heat and light. Such materials are used in electric heaters and toasters. Fine wires resist the flow of electricity more than thick wires do, and this fact is used in making electric lights. *Tungsten* is a material that not only resists the flow of electricity but can be made white-hot without melting. The fine wires that glow white in the ordinary electric light are made of this material.

Do you see how varied are the uses of electricity? Do you see that this mysterious energy is so useful chiefly because it can be easily changed into so many different forms?

THE STORY OF ENERGY

In the Very Early Days. The beginning of the story of energy lies far back in the early history of man. Think for a moment how primitive man lived and worked. If a heavy load had to be moved, he carried it on his back. Such tools as he had were very crude. Perhaps a stone tied to the end of a stick was used both as a hammer and a club. Sharp stones were used for knives. The beams of his hut were lifted into place by hand. For all his work primitive man had but one kind of energy—the energy of his own muscles.

Galloway

The pyramids of Egypt are mighty monuments to the energy of muscle

Let us come down a little closer to our own day. Thousands of years ago, when the kings of Egypt built the pyramids, countless men and animals worked hard to cut the huge blocks of stone and to move them over the land to the edge of the Sahara Desert. As you look at the size of the blocks as pictured above, it is very easy to believe an ancient writer who tells us that a hundred thousand men had to work for twenty years to build just one of these pyramids. Again the source of energy was muscle.

In the Days of Our Great-grandfathers. But, you may say, this was a long, long time ago. True, but we find the same form of energy used very widely in the days of our own great-grandfathers. A trip of one hundred miles was then an important event. It took several days to make such a journey in a swaying stagecoach which jolted and bounced over rough and muddy roads. Energy was still provided largely by the muscles of men and beasts. It is only during very recent times that men have learned to use other kinds of energy.

The Empire State Building is a mighty monument to the energy of gasoline, steam, and electricity

The Machine Age. The present is often called the Machine Age because machinery is used to do a great deal of the world's work. Contrast the building of the pyramids with the building of a modern skyscraper. The Empire State Building in New York City is one of the great structures of modern times. It rises more than a quarter of a mile above the street. There are eighty-six floors of offices. On each floor are hundreds of square feet of office space. *Yet only a few hundred men were employed in the construction of the Empire State Building, and the work was completed in less than one year.* These men used modern power-driven machinery: motor trucks, steam engines, and derricks.

In the days of the stagecoach very few people ever traveled as far from home as Philadelphia is from New York. Today as many as three trainloads of people leave New York City for Philadelphia every daylight hour and on every day of the year. Many more trainloads travel at night. In addition to this, passenger airplanes cover the same distance every hour the sun is shining. Over the great highways that connect these two cities there is an almost continuous line of automobiles. And this is just one example of the modern use of machinery!

It is hard for us who live in the midst of this Machine Age to realize that *most of the machinery we use is very new.* Railroads a hundred years ago, for example, were slow and not very reliable. In 1831 the directors of the Baltimore and Ohio Railroad offered a prize of five thousand dollars for the best locomotive built in this country. The directors considered only such engines as could travel at fifteen miles per hour and pull a load of fifteen tons over a level track.

On page 451 an artist has pictured the locomotive that

From painting by Herbert D. Stitt

Who would have suspected that the little locomotive of yesterday
could have become father to the mighty flyer of today?

© Science Museum, London

Travel was slow and uncertain a century and a half ago

won the prize. In the picture he has also faintly suggested the locomotive of today, which may weigh as much as four hundred and fifty tons. It can pull a train weighing more than fifteen thousand tons with a speed of more than eighty miles per hour. How different these engines are! The same is true of many other machines with which we are familiar. Contrast the means of transportation pictured above with that shown on the opposite page.

New Uses for Energy. Every day sees new uses for energy. Factories that once employed hundreds and thousands of men now produce the same amount of material with just a handful of workers who press buttons and move levers. Machines throw switches, close doors, and do many other things with greater regularity than men can do these things. Energy from fuels is rapidly replacing energy from men's muscles. The power plants in this country, for example, are producing fourteen times as much power today as they did only twenty years ago. Over a short space of twenty-five years the number of hours of human labor required to produce an automobile has been reduced from 1291 to 92. Machines today make 40,000 bricks an hour as against the old rate of 55 an hour.

The Problem of Unemployment. Where is all this leading us? It has already led us away from back-breaking, dreary work, for which we may all be thankful. It has made our lives more comfortable in many ways. But it has also made problems which our ancestors never had.

Though new inventions make a certain number of new jobs, machinery as a whole has deprived a great many workmen of work. Unemployment is one of the greatest problems of the modern world, and it is a problem for which machinery is partly to blame.

The transport plane is the greatest triumph of modern travel

Galloway

The problem, however, is not hopeless. Men have learned to adjust themselves to difficult conditions in the past, and they will someday learn to adjust themselves to machinery. When they do, they may well enjoy such comfort and safety as our grandfathers never dreamed could exist.

THE CONSERVATION OF ENERGY RESOURCES

The Minor Sources of Energy. Now that men are more and more turning to other sources of energy than their own muscles, we may well take stock of the energy resources of the world. What sources of energy are now in use? How long will they last? What shall we do when the supply runs out?

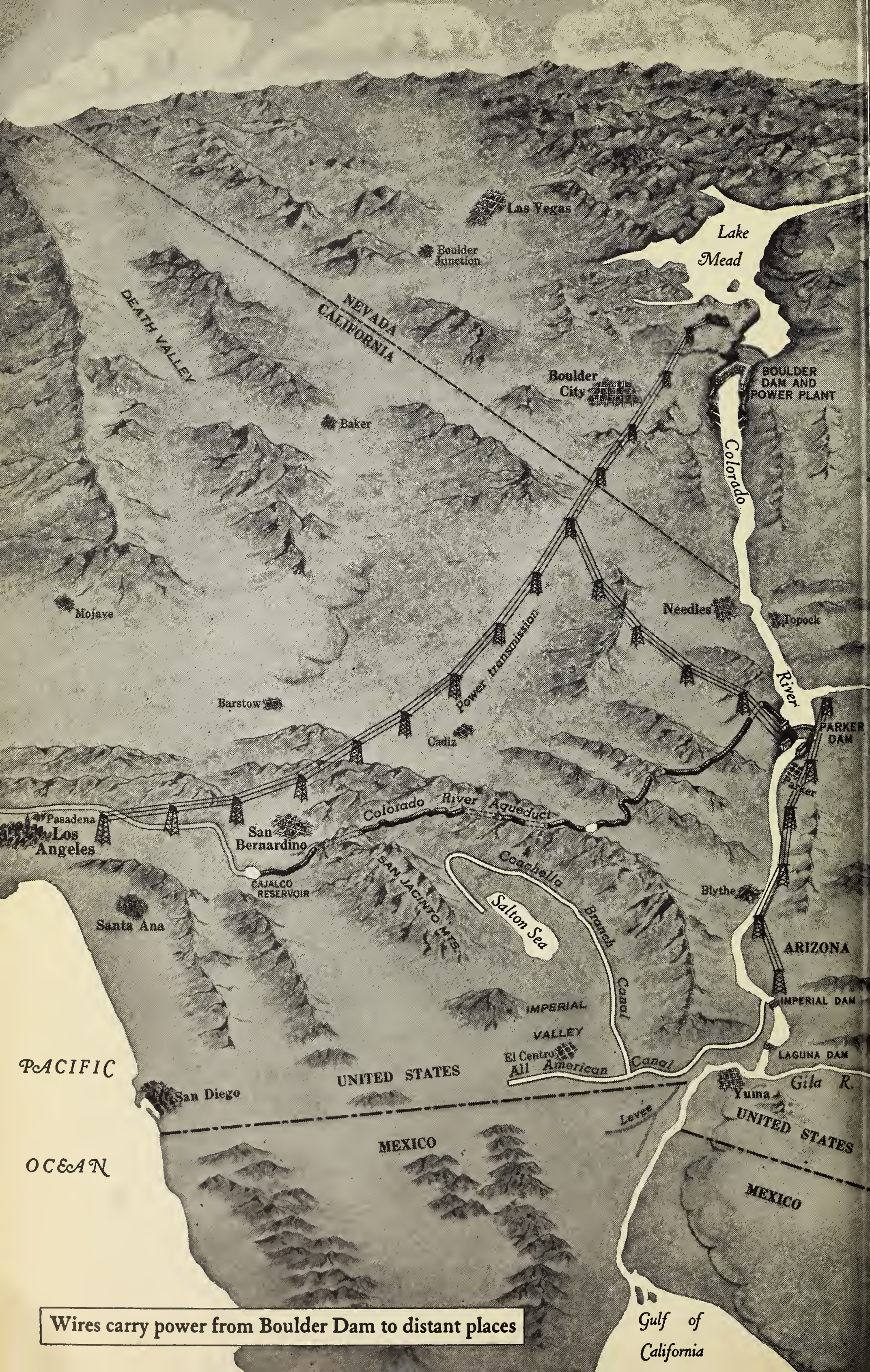
Some of the work of the world will probably always be done by the muscles of men and beasts. Muscle, however, will never again be an acceptable source of energy for large-scale undertakings. The world has outgrown muscle just as it has outgrown silent movies. Nor is wind ever likely to provide more than a minor amount of the world's energy. In the past, wind has been widely used to move boats and to pump water from the ground, but it is unsatisfactory chiefly because it is unsteady. As long as coal and oil may be had for these purposes, most people will prefer them to any other source of energy.

The Conservation of Water Power. In Chapter VI we saw how the industrial history of America began when the people of New England harnessed the energy of their rivers. For many years the factories that used this kind of energy were chained to the banks of the rivers that supplied it. Not until 1882 was running water used to generate electricity. From then on the development of water power leaped ahead. In many localities water power was turned into electricity and carried away from the streams in wires to places where the power could be most conveniently used.

Today about 10 per cent of the total energy output of the United States comes from the power of running water. "Why," you might well ask, "is this percentage so small?" The answer is that the cost of building dams to hold back enough water to provide a steady supply—to say nothing of the expense of installing the power plants themselves—is very high. The best sites in this country for such plants were soon occupied by private companies. With coal and oil still cheap (and therefore still in competition with water as sources of power) private companies have hesitated about taking on the costly task of developing the more remote streams.

The United States government, however, has not hesitated. Boulder Dam, where power is developed in the Colorado River and sent some two hundred and seventy miles through wires to Los Angeles, was built at a cost that only a very rich government could afford. In the long run such projects are expected to pay for themselves through the sale of power and also of water for irrigation.

The people of this country are coming to realize that *dams can and should serve more purposes than merely the production of power.* They can be among the most effective means of flood control by holding back the water along the swift feeder streams of rivers. Also by holding back the water they make it possible for more water to soak into the ground, and so can help to keep the underground water over large areas at proper levels for the good of soil and crops. They can provide homes for large numbers of people by irrigating desert lands. By raising the level of the water



Wires carry power from Boulder Dam to distant places in the rivers above them they can make navigation possible on many inland waterways and thus reduce the cost of transportation.

So it is that in the future the conservation of water power will doubtless become tied up with many other forms of conservation. It will involve engineering feats on a scale never before attempted by man. It will be largely a government undertaking—not for the immediate profit of a few people but for the lasting good of all.

Exercise. Look up and report on the Tennessee Valley Authority. This is one of the largest development and conservation projects in the world today.

The Conservation of Coal. The proper use of water power makes no drain on the energy resources of the world. Next week, next month, or next year the rains will come and return what man has taken. Quite the reverse is true in the use of coal, which is our greatest source of energy today. Like all other mineral deposits on earth, coal was very long in forming. Deposits of coal are decidedly limited in extent. When all these deposits are mined and burned, one very important source of energy will be gone forever.

Though there is still a great deal of coal in the ground, we are removing it at the rate of one to two billion tons a year. We are wasting far more than we remove. Competition in mining and selling coal has led the coal companies to mine only the thickest and richest seams and those which lie nearest the surface of the earth. Much coal in the thinner, poorer, and deeper seams has been left in the ground. Many mines have then been abandoned, the roofs have caved in, and the tunnels have been flooded with water. A large number of old mines have thus been so badly damaged that they can never be profitably reopened.

Much coal is consumed in carrying it to the factories and homes that use it. Many millions of tons are burned every year to supply power for carrying other millions of tons from the mine to the consumer. By far the greatest waste of coal, however, is due to uneconomical methods of using it. The clouds of smoke that hang over our great cities are made very largely of poorly burned coal. They are a symbol of the recklessness with which we squander our natural wealth.

Fortunately there is a brighter side to this picture. Mining methods have perhaps become a little less wasteful in recent years. Power plants that use coal have certainly become a great deal less wasteful. Modern locomotives are so efficient that they have cut down their coal consumption to about two thirds of what it once was. Heating plants, particularly those of the central type which supply heat to several near-by buildings, greatly help to reduce the national waste of coal. In spite of all these improvements, however, it is estimated that on the average only 4 per cent of the energy which is stored in coal in the ground is converted into energy that can be used!

Exercise. Visit a factory in your neighborhood that uses coal, and see if you can discover any waste of coal or of the energy taken from the coal. Write a report for your class on your conclusions.

The Conservation of Petroleum. Of all the waste that the United States has indulged in, the waste of oil (petroleum) has probably been the most reckless. Though the petroleum industry is only about half a century old, petroleum has grown from a rare substance used as medicine to one of the most widely used minerals in the world. Over three hundred products of this mineral are now on the market, and each year sees the arrival of new ones. As someone once remarked, every part of petroleum can be used except the smell.

The main use of petroleum, however, is for fuel. Occurring chiefly as a liquid in underground pools, it can easily be obtained by drilling. People attempting to get rich quickly have greatly abused the oil reserves of America.

Here is just one way in which we burn up our natural wealth

Meyers

In their haste to beat their competitors to the market they have drilled carelessly and have wasted millions and millions of barrelfuls through leaks, evaporation, fire, and in other ways. The photograph on page 459 shows what has happened to no little of our petroleum wealth.

As in the case of coal, methods of obtaining and using petroleum are becoming less wasteful with time. Nevertheless we still waste much more of both these valuable materials than we use. In spite of all possible conservation measures, the days of these energy-producers are numbered. What shall we do when they are entirely gone? Nobody can answer that question. It is hopeful to observe that man has always been able to find the energy he needed; probably he will always be able to do so. Coal and petroleum, however, are much the most practical sources of energy for most purposes today. We should all try to make them last as long as possible.

Exercise. Mark the major oil fields of the United States on an outline map. Mark the fields whose production has fallen off since 1920 in red and other fields in black. You can get the necessary information from the "National Resources Board Report" of 1934 or from a variety of books on the oil industry.

The End of This Book. So we come to the end of this book. We have seen how all the worlds which make up the world around us are tied into one great active whole.

Though we have come to the end of this book, we have not come to the end of the world. The world around us will continue to exist. It will continue to be interesting and worth exploring. This book has shown you how to explore it. Let us hope that it has also made you want to go on exploring it as long as you live.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The world is full of energy, but wherever we go we find energy in only one form.

2. The earth is the only object in the universe that contains the energy of gravity.

3. A pound always contains 16 ounces.

4. Gravity is nothing but a hindrance to man because it pulls on everything and so makes moving and lifting difficult.

5. The energy which plants use comes from the sun, but the energy which animals use does not.

6. When sidewalks are intensely heated, they sag.

7. The energy of steam was unknown until Watt invented the steam engine.

8. Steam is being used less and less in the modern industrial world.

9. Coal is rather generally taking the place of petroleum as a source of heat.

10. Electricity is the most difficult type of energy to produce and control.

11. An electromagnet is a certain kind of iron compound which can attract other pieces of iron to itself, and which the ancients discovered centuries before Christ.

12. Electricity can be turned into the energy of motion, but the energy of motion cannot be turned into electricity.

13. More men were needed to build the Empire State Building than the pyramids.

14. When all the coal and oil have been used, we can turn to the wind as a satisfactory source of energy.

15. The future of water power will depend on the willingness of private people to invest in expensive dams and power plants.

16. You have now learned everything there is to know about the world around us.

Questions for Discussion

1. Do you think you would weigh more or less if you were standing at the north pole than if you were standing at the equator? Why?

2. Which of the fuels in common use do you consider the most convenient producer of heat energy? Why?

3. It is often said that electricity is the most useful form of energy available to man at the present time. Is this statement true or false? Why?

4. Should people be actively interested in the conservation of energy resources such as coal and oil? Why?

Things to Do

1. Write a story about an imaginary land where no such thing as gravity exists. Let your imagination make a good story, but be sure that your statements are scientifically correct.

2. Investigate and report on the common methods of heating homes. This report might include the heating of homes in the past as well as the present. Use pictures and diagrams to illustrate your report.

3. You may want to do some simple experiments with magnets and electricity. Several good books have been written on electricity for boys and girls. Do a few experiments with the help of one of these books, and keep a record of them in your science notebook.

4. Make a survey of your community to find out what forms of energy are most commonly used. You might make your report in the form of a chart showing (*a*) the kind of energy; (*b*) what the energy is used for; (*c*) source of each kind of energy; (*d*) waste of each kind of energy.

5. Read *The Boy's Life of Edison*, by W. H. Meadowcroft. As you read it think how Edison helped in man's efforts to control energy.

6. Look up Stuart Chase's *The Tragedy of Waste* and *Rich Land, Poor Land*; Katherine Glover's *America Begins Again*; the issue of *Building America* which deals with conservation (Vol. 2, No. 7); *Conservation in the United States*, by Gustafson, Ries, Guise, and Hamilton. All these publications deal interestingly not only with the conservation of energy resources but also with many other types of conservation.

Readings in Science

ANDRESS, J. MACE, GOLDBERGER, I. H., and HALLOCK, GRACE T. *Helping the Body in Its Work.* Ginn and Company, Boston.

A straightforward, simple physiology for older boys and girls, with an entire unit devoted to safety.

BAER, MARIAN. *Pandora's Box.* Farrar & Rinehart, Inc., New York, 1939.

A story of conservation of our natural resources.

BAER, MARIAN. *The Wonders of Water.* Farrar & Rinehart, Inc., New York, 1938.

A description of the properties of water in simple language with interesting illustrations.

BORTH, CHRISTY. *Pioneers of Plenty.* Bobbs-Merrill Company, Indianapolis, 1939.

A description of the new discoveries and products in chemistry on the farm and in the forest.

BRADLEY, JOHN H., JR. *Parade of the Living.* Coward-McCann, Inc., New York, 1930.

The author traces vividly the procession of living forms that has occurred on this earth. He takes up the structure of the earth, the earliest forms of life, the appearance and disappearance of various animal kinds, disease, intelligence, and so on.

BRONSON, WILFRED, S. *The Wonder World of Ants.* Harcourt, Brace and Company, New York, 1937.

A simple little story telling how ants live.

BROOKS, C. F. *Why the Weather?* Harcourt, Brace and Company, New York, 1935.

A revised edition of a popular book answering a great many questions about the weather.

BUCK, FRANK. *On Jungle Trails.* World Book Company, Yonkers-on-Hudson, 1936.

A description of jungle animals in their natural habitat.

Buck, Frank, and Frazer, Ferrin. *Fang and Claw.* Simon & Schuster, Inc., New York, 1935.

Animals of the African jungle and how they are adapted to conditions.

Collins, A. F. *Fun with Electricity.* D. Appleton-Century Company, Inc., New York, 1936.

A book of tricks and experiments illustrating some important ideas in the area of energy transformations.

Curie, Eve. *Madame Curie.* Doubleday, Doran & Company, Inc., New York, 1938.

This inspiring biography of the woman who discovered radium, by her daughter, should be one of the long-remembered books of our time.

de Kruif, Paul. *Men against Death.* Harcourt, Brace and Company, New York, 1932.

This book, like *Microbe Hunters*, consists of biographical sketches telling about recent scientific discoveries that doctors are making in the fight against disease.

de Kruif, Paul. *Microbe Hunters.* Harcourt, Brace and Company, New York, 1930.

Interesting biographical sketches of such men as Pasteur, Koch, Roux, Bruce, Reed, and Ehrlich, give some of the drama of their history-making discoveries and some appreciation of their significance to us.

Disraeli, Robert. *Seeing the Unseen.* John Day Company, Inc., New York, 1933.

On using the microscope to see plant and animal life, with photomicrographs by the author.

Ditmars, Raymond Lee. *The Book of Living Reptiles.* J. B. Lippincott Company, Philadelphia, 1936.

Stories of crocodiles, alligators, turtles, and lizards in their native habitats, with colored illustrations.

Ditmars, Raymond Lee. *Snakes of the World.* The Macmillan Company, New York, 1931.

This gives interesting descriptions of snakes and their habits, together with eighty-four remarkable full-page photographs of them.

Eaton, Jeannette. *The Story of Light.* Harper & Brothers, New York, 1937.

From the discovery of fire to the modern incandescent lamp. Well written and interesting.

EATON, JEANNETTE. *The Story of Transportation.* Harper & Brothers, New York, 1937.

From Indian trails through sailing boats, trains, and steamboats to the airplane.

EMERSON, CAROLINE D. *Father's Big Improvements.* Frederick A. Stokes Company, New York, 1936.

"Water did not always run in pipes, and wires did not always carry messages." Many changes have taken place in one lifetime because of scientific progress. This little book tells about some of them.

FENTON, CARROLL L. *Along the Hill.* Reynal & Hitchcock, Inc., New York, 1935.

A small guidebook about rocks and fossils.

FENTON, CARROLL L. *Our Amazing Earth.* Doubleday, Doran & Company, Inc., New York, 1938.

A description of earth changes and of the living things that have existed under these changing conditions.

FISK, DOROTHY M. *Exploring the Upper Atmosphere.* D. Appleton-Century Company, Inc., New York, 1935.

A book about the stratosphere and properties of the upper air.

FISK, DOROTHY M. *Modern Alchemy.* D. Appleton-Century Company, Inc., New York, 1936

A simply written description of the newer discoveries in physics.

FRANCIS, MARGARET FOX. *Flowers and Their Travels.* Bobbs-Merrill Company, Indianapolis, 1936.

Where our plants came from and how they got here.

FURNAS, C. C. *The Next Hundred Years.* Reynal & Hitchcock, Inc., New York, 1936.

"The unfinished business of science," with descriptions of what has already been accomplished.

FURNAS, C. C. *Storehouse of Civilization.* Teachers College, Columbia University, New York, 1939.

A story of the earth's minerals and how we use them, including the story of energy.

GLOVER, KATHERINE. *America Begins Again.* McGraw-Hill Book Company, Inc., New York, 1939.

The story of how America has begun to conserve its natural resources.

HALL, CHARLES GILBERT. *Skyways.* The Macmillan Company, New York, 1938.

An up-to-the-minute history of aviation, with many illustrations.

HODGINS, E., and MAGOUN, F. A. *Sky High.* Little, Brown and Company, Boston, 1937.

A history of aviation from the fourth century B.C. until today.

HOLWAY, HOPE. *The Story of Water Supply.* Harper & Brothers, New York, 1930.

This gives an elementary, yet interesting, story of the development of various ways of obtaining a water supply.

HOUSE, HOMER D. *Wild Flowers.* The Macmillan Company, New York, 1934.

Color plates, in natural size, of the common wild flowers of New York and other northeastern states.

INNES, WM. T. *Exotic Aquarium Fishes.* Innes Publishing Co., Philadelphia, 1935.

Most unusual colored illustrations and descriptions of tropical fish, together with suggestions for care of these fish. The author is a leading authority in the field.

KENLY, JULIE CLOSSON. *Cities of Wax.* D. Appleton-Century Company, Inc., New York, 1935.

The life story of bees, with emphasis on their activities as social insects.

KENLY, JULIE CLOSSON. *Green Magic.* D. Appleton-Century Company, Inc., New York, 1930.

This tells simply and well the life story of flowering plants.

KNIGHT, CHARLES R. *Before the Dawn of History.* McGraw-Hill Book Company, Inc., New York, 1935.

The illustrations are reproductions of Knight's paintings at the American Museum of Natural History. Brief stories go with each picture.

LINDBERGH, ANNE MORROW. *Listen! The Wind.* Harcourt, Brace and Company, New York, 1938.

Even more interesting perhaps than *North to the Orient*, this book tells of the author's experiences in air travel about the world.

LONGSTRETH, T. M. *Reading the Weather.* The Macmillan Company, New York, 1938.

Nontechnical discussion of the commoner weather facts.

LORD, RUSSELL. *Behold Our Land.* Houghton Mifflin Company, Boston, 1938.

The menace to the nation in agricultural wastage.

LORENTZ, PARE. *The River.* Stackpole Sons, New York, 1938.

A description, with pictures, of the effect of rivers on human living. Script of United States documentary film of the same title.

LYMAN, L. D., and ALLEN, C. B. *Wonder Book of the Air.* John C. Winston Company, Philadelphia, 1938.

Chiefly about aviation of the present day.

MCCLINTOCK, THEODORE. *The Underwater Zoo.* Vanguard Press, Inc., New York, 1938.

A day-by-day journal of adventures with fresh-water insect life.

MCCREERY, JAMES LINDSAY. *Exploring the Earth and Its Life in a Natural History Museum.* Frederick A. Stokes Company, New York, 1933.

As the title indicates, this book serves as a guide to the discovery of the big ideas and relationships that may be learned from exhibits in museums. It is splendidly done.

MERIWETHER, SUSAN. *The Story of the Telephone.* Harper & Brothers, New York, 1937.

The history of communication leading up to the modern telephone.

MILLS, CLARENCE A. *Living with the Weather.* Caxton Press, New York, 1935.

How weather affects us, and what we can do about it.

MORGAN, ALFRED. *Things a Boy Can Do with Electricity.* Charles Scribner's Sons, New York, 1938.

An excellent book to acquaint the student with electricity.

MUENSCHER, WALTER C. *Weeds.* The Macmillan Company, New York, 1935.

A book for reference, with descriptions and a botanical key, so that you may know weeds and what to do about them.

PEARSON, T. GILBERT. *Birds of America.* The Garden City Publishing Company, Inc., New York, 1936.

Pictures, many in color, and descriptions of all the common birds in the United States.

Peattie, Donald Culrose. *Green Laurels.* Simon & Schuster, Inc., New York, 1936.

Story of the discovery of the living world, through the biographies of the men who led in the discoveries.

Pickwell, Gayle. *Deserts.* McGraw-Hill Book Company, Inc., New York, 1938.

Vivid description of the plants and animals of the desert and their adaptations to it.

Pope, Clifford H. *Snakes Alive.* Viking Press, Inc., New York, 1937.

How snakes live, with an illustrated key for identifying the snakes of the United States.

Post, Augustus. *Skycraft.* Oxford University Press, New York, 1933.

This book gives, in interesting fashion, information about all kinds of airplanes. The new models are shown in illustrations.

Reed, W. M. *The Earth for Sam.* Harcourt, Brace and Company, New York, 1930.

There are chapters describing the air we breathe, mountains and rivers, and glaciers.

Reed, W. M., and Bronson, W. S. *The Sea for Sam.* Harcourt, Brace and Company, New York, 1935.

Another book for Sam, written by his uncle. This one tells about the life of the sea.

Shannon, Howard J. *The Book of the Seashore.* Doubleday, Doran & Company, Inc., New York, 1935.

"Where life goes on between the tides."

Teale, Edwin W. *The Boy's Book of Insects.* E. P. Dutton & Co., Inc., New York, 1939.

A beautifully illustrated book about common insects, with photographs by the author.

Teale, Edwin W. *Grassroot Jungles.* Dodd, Mead and Company, New York, 1937.

Excellent photographs and descriptions of the common creatures in the "jungles" under our feet.

Washburne, Carleton, and Washburne, H. C. *The Story of the Earth and Sky*. D. Appleton-Century Company, Inc., New York, 1933.

A treatment of the earth and sky in story form, including a unit on scientific method.

Wilder, Louise B. *The Garden in Color*. The Macmillan Company, New York, 1937.

Over three hundred natural-color plates of garden flowers from early spring to late autumn.

Wilhelm, Donald. *The Story of Iron and Steel*. Harper & Brothers, 1937.

The story of two metals of first importance to civilization from primitive days to modern methods of refining.

Woodbury, David. *The Glass Giant of Palomar*. Dodd, Mead and Company, New York, 1939.

A story of the making of the new telescope for Mt. Palomar, with emphasis on the scientific problems involved.

Science Words

KEY TO THE SOUNDS

ă *as in* at
ā *as in* ate
â *as in* care
ȧ *as in* ask
ä *as in* arm
a̭ *as in* sofa
ĕ *as in* bet
ē *as in* be
ẽ *as in* her
ḙ *as in* vowel
ĭ *as in* bit
ī *as in* bite
ŏ *as in* got
ō *as in* go
ô *as in* horse
o̭ *as in* connect
oi *as in* oil
o͝o *as in* foot
o͞o *as in* food
ŭ *as in* us
ū *as in* use
ṷ *as in* circus
t͜ū *as in* nature
ŋ *as in* ink

abdomen (ăb dō′mĕn). In insects, the rear section of the body (p. 322)[1]

acid (ăs′ĭd). A compound which has a sour taste when dissolved in water. All acids contain hydrogen (p. 253)

adaptation (ăd ăp tā′shṷn). Change of the structure or behavior of a plant or animal or of its parts. In this way it becomes better fitted for living in its environment (p. 363)

aeration (ā ẽr ā′shṷn). Mixing with air. Sometimes "aeration" is used to mean mixing with some other gas, such as carbon dioxide (p. 112)

air conditioning. A way in which air is kept at a comfortable temperature and state of humidity. Theaters, factories, and railroads are some of the users of this process (p. 224)

air pressure. The weight of air pressing on a surface. At sea level the pressure of the air is about 15 pounds per square inch; at higher altitudes, it is less (p. 167)

air pump. A pump used for taking air out of a container; also, a pump used for compressing air (p. 166)

alcohol (ăl′kō hôl). A colorless liquid composed of carbon, hydrogen, and oxygen. Wood alcohol and grain alcohol are only two of the many kinds of alcohol (p. 83)

alga (ăl′ga̭) [plural *algae* (ăl′jē)]. The lowest group of green plants. They have no definite root, stem, or leaf, and usually live in water Seaweeds and pond scums are algae (p. 342)

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[1] References are to pages in the text where the words first occurred.

alum (ăl'ụm). A white compound of aluminum, used to purify water. Physicians use it to stop bleeding (p. 119)

aluminum (ạ lū'mĭ nụm). A bluish-silver-white element. It is a metal especially useful where light weight is important. Its compounds are very abundant in nature (p. 191)

amber (ăm'bẽr). A fossil resin which is yellow to brown in color. It is hard and brittle and takes a fine polish (p. 443)

ammonia (ă mō'nĭ ạ). A colorless gas composed of nitrogen and hydrogen. Ordinary ammonia is a solution of this gas in water (p. 119)

ammonium chloride (ă mō'nĭ ụm klō'rīd). A white compound of nitrogen, hydrogen, and chlorine. When powdered, it is used for filling dry cells (p. 445)

anemone (ạ nĕm'ō nē). A plant whose large showy flowers have no petals but do have conspicuous sepals (p. 318)

antifreeze (ăn tĭ frēz'). A liquid having a low freezing point. When added to the water in the radiator of an automobile, it prevents the freezing of the cooling system during cold weather (p. 83)

antiseptic surgery (ăn tĭ sĕp'tĭk sẽr'jẽr ĭ). Operations on people in which extreme care is taken not to let the wound become infected (p. 40)

aquarium (ạ kwâr'ĭ ụm). A jar or tank in which water plants and animals may live and be studied (p. 58)

aqueduct (ăk'wē dŭkt). A pipe which carries large amounts of water to a city (p. 112)

argon (är'gŏn). A gas which is present in the air in very small amounts. It is used in some electric-light bulbs (p. 198)

Aristotle (ăr'ĭs tŏt'l) (384–322 B.C.). A Greek thinker who greatly influenced the study of science for more than two thousand years (p. 36)

astronomer (ăs trŏn'ō mẽr). A person who carefully observes the stars and other bodies in the heavens (p. 20)

athlete's foot. A skin disease, called ringworm, caused by a mold. It is often acquired in gymnasium showers and in the walks around swimming pools (p. 208)

auk (ôk). A diving bird which breeds in the colder parts of the Northern Hemisphere (p. 357)

autogiro (ô tō jī'rō). An airplane built so that it can land and take off almost vertically (p. 40)

bacteria (băk tēr'ĭ ạ) [singular *bacterium* (băk tēr'ĭ ụm)]. Plants so small that they can be seen only through a microscope. Many bacteria cause diseases, but many others are very useful to man (p. 108)

bacterial diseases. Diseases caused by bacteria (p. 226)

balance of life. The condition in nature in which the smaller and weaker animals are more abundant than the larger and stronger animals, and thus are able to survive (p. 347)

ball bearing (bôl bâr′ĭng). A device for lessening friction. The revolving part turns on hard loose steel balls which roll easily (p. 433)

barnacle (bär′na̯ k’l). A small sea animal with a white shell. Groups of barnacles can be found attached to rocks, floating logs, and ships’ bottoms (p. 350)

barometer (ba̯ rŏm′ē tẽr). An instrument used to measure air pressure (p. 172)

basalt (ba̯ sôlt′). A dark-colored, fine-grained rock which was formed by heat (p. 241)

beriberi (bĕr′ĭ bĕr′ĭ). A nervous disease caused by insufficient vitamin B in the diet (p. 410)

boiling point. The temperature at which a liquid boils. For water under ordinary pressure this is 212° F. or 100° C. (p. 79)

cactus (kăk′tu̯s) [plural *cacti* (kăk′tī)]. A plant which can live in an extremely dry environment. It has fleshy stems and branches with scales and spines instead of leaves (p. 305)

calcium (kăl′sĭ u̯m). A silver-white soft metal whose compounds occur in nature. Some of its compounds are chalk, shell, and limestone (p. 283)

cambium (kăm′bĭ u̯m). The growing part of many plants. In a tree the cambium is the soft tissue beneath the bark which gives rise to new bark and new wood (p. 310)

carbohydrate (kär bō hī′drāt). Food that is a compound of carbon, hydrogen, and oxygen. Sugar and starches are examples of carbohydrates (p. 398)

carbon (kär′bo̯n). An element which is contained in all living materials. Charcoal and coal are impure forms of carbon (p. 189)

carbon dioxide (kär′bo̯n dī ŏk′sīd). One of the gases in the air. It is a nonpoisonous product of respiration and of burning, and is needed by plants for food-making. In solid form it is known as "dry ice" (p. 64)

carbon monoxide (kär′bo̯n mŏn ŏk′sīd). A poisonous gas which is both colorless and odorless. It is formed when there is not enough oxygen present for carbon to burn completely (p. 215) *carbon tetrachloride* (kär′bo̭n tĕt ra̭ klō′rīd). A colorless liquid compound of carbon and chlorine. It will not burn (p. 201)

carbonic (kär bŏn′ĭk) *acid*. The acid formed when carbon dioxide is dissolved in water (p. 263)

carbureter (kär′bū rĕt ẽr). A mechanism in an automobile or other gas engine which mixes gasoline vapor with air (p. 216)

carnivorous (kär nĭv′ō rṷs). Flesh-eating (p. 348)

caste (kȧst). A division or group within any community (p. 346)

cell. The smallest complete unit or part of living matter (p. 52). A means by which chemical energy can be changed to electric energy (p. 445)

centigrade (sĕn′tĭ grād). A thermometer scale which is marked so that there are 100 degrees between the freezing point of water (0° C.) and the boiling point (100° C.) (p. 79)

cesspool (sĕs′pōōl). A drain or pit for the collection of sewage (p. 116)

chemistry (kĕm′ĭs trĭ). The branch of science which deals with the changing of one substance into another (p. 201)

chlorine (klō′rēn). A heavy, greenish-yellow poisonous gas with a suffocating odor (p. 111)

chlorophyll (klō′rō fĭl). The green coloring matter of plants (p. 312)

clam. A small water animal with two somewhat regular shells, each covering half of its soft body (p. 56)

classification (klăs ĭ fĭ kā′shṷn). Arrangement of plants or animals or things according to their likenesses (p. 233)

compound (kŏm′pound). A substance which is formed from at least two elements and which has properties different from those of either of them (p. 192)

compressed air. Air which is pressed together more than is usual; for example, the air in automobile tires (p. 168)

condor (kŏn′dẽr). A very large vulture (p. 357)

conductor (ko̭n dŭk′tẽr). A substance which will allow electricity to travel through it (p. 446)

conglomerate (ko̭n glŏm′ẽr ĭt). A rock composed of rounded rock fragments of different sizes cemented together by hardened clay (p. 250)

conservation (kŏn sẽr vā′shṷn). The protection of our natural wealth from loss or injury (p. 145)

copper sulfate (kŏp′ẽr sŭl′fāt). A poisonous copper compound, often called blue vitriol (p. 103)

crop rotation. The planting of crops in such an order that those which remove minerals from the soil are followed by those which give minerals back to the soil (p. 283) *crust of the earth.* The outer zone of the earth, the part on which we live and which we can study by observation (p. 254)

cylinder (sĭl′ĭn dẽr). A solid or shell with rounded sides and a circular surface for both top and base (p. 14). Hollow cylinders made of metal are parts of steam and gas engines. In the cylinder of the automobile engine the vapor is compressed and exploded (p. 216)

deficiency diseases. Diseases which result from the lack of something in the diet. Beriberi, scurvy, and pellagra are deficiency diseases (p. 411)

diphtheria (dĭf thēr′ĭ a̯). A disease caused by bacteria which live in the throat and produce a poison which enters the blood (p. 210)

dissolve (dĭ zŏlv′). To mix two or more substances so thoroughly that their separate particles cannot be seen even through a very powerful microscope. For example, when sugar dissolves in water, its particles are completely invisible (p. 64)

distillation (dĭs tĭ lā′shu̯n). The process of changing a liquid to a vapor and then cooling and condensing the vapor back to a liquid (p. 106)

draft (drȧft). A current of air (p. 174). A device to control the currents of air in a fireplace, stove, or furnace (p. 216)

dysentery (dĭs′e̯n tĕr ĭ). A disease of the intestines caused by microscopic plants and animals (p. 210)

electromagnet (ē lĕk trō măg′nĕt). A piece of soft iron surrounded by a coil of wire through which an electric current is passed (p. 446)

element (ĕl′ē me̯nt). A substance composed of only one kind of material. There are 92 known elements, which combine to make all the other substances we know (p. 191)

embryo (ĕm′brĭ ō). The young of a plant or an animal in its earliest stages of development. A chick embryo is the chick before being hatched from the egg (p. 319)

energy (ĕn′ẽr jĭ). The ability to move objects. Energy may be present even when objects are not in motion. Heat, light, and electricity are forms of energy (p. 423). Certain foods are especially important in producing energy for the body (p. 399)

environment (ĕn vī′ru̯n me̯nt). The objects and forces around us or around any living thing (p. 364)

ether (ē′thẽr). A liquid used in surgery. It evaporates readily and burns easily (p. 201)

evaporation (ē văp ō rā′shu̯n). The change from a liquid to a gas (p. 84) *exhaust* (ĕg zôstʹ). The used gases escaping from the cylinders of an automobile or other engine (p. 216)

extinction (ĕks tĭngkʹshu̯n). Complete destruction (p. 355)

Fahrenheit (fărʹe̯n hīt). A thermometer scale which is marked so that there are 180 degrees between the freezing point of water (32° F.) and the boiling point (212° F.) (p. 79)

feldspar (fĕldʹspär). The most abundant of all the minerals in the earth's crust (p. 238)

fertilizer (fẽrʹtĭ līz ẽr). Any substance added to the soil for the purpose of aiding plant growth (p. 274)

flounder (flounʹdẽr). A flat fish (p. 368)

flow structure. The condition resulting from the moving of molten rock. The minerals in the rock are lined up in a somewhat regular order (p. 243)

food chain. The manner in which living things are linked to one another by the necessity of eating and of being eaten (p. 304)

force (fōrs). A push or a pull; that which makes objects move (p. 174)

freezing point. The point at which a liquid changes to a solid. The same as the melting point. In water, 32° F. or 0° C. (p. 66)

friction (frĭkʹshu̯n). The resistance or drag brought about when two substances are rubbed together (p. 432)

fungi (fŭnʹjī) [singular *fungus* (fŭŋʹgu̯s)]. Plants that have no green chlorophyll, such as mushrooms and mildews. Fungi cannot make their own food, but live on other plants. They produce spores but never seeds (p. 332)

Galileo (găl ĭ lēʹō) (1564–1642). An outstanding Italian scientist. Among other things he proved that planets move around the sun (p. 36)

gas. A substance that takes the volume and shape of the object which contains it (p. 44)

generate (jĕnʹẽr āt). To produce; for example, steam may be generated in a boiler and may be used to generate electricity (p. 454)

gibbon (gĭbʹu̯n). A kind of small tailless ape found in southeastern Asia and the East Indies (p. 376)

gill (gĭl). An organ for breathing under water. Fish and some other water animals have gills (p. 65)

glacier (glāʹshẽr). A mass of slowly moving snow and ice that does not melt even in summer (p. 246) *gneiss* (nīs). A rock formed by the action of heat and pressure on granite (p. 254)

goiter (goi'tẽr). An enlargement of a gland in the neck. Goiter may develop when iodine is lacking from the diet (p. 409)

granite (grăn'ĭt). A coarse igneous rock in which grains of quartz, feldspar, and mica may be seen (p. 237)

grassland (grȧs'lănd). Grass-covered ground (p. 146)

gravity (grăv'ĭ tĭ). The force which pulls objects on or near the surface of the earth toward its center. The attraction between the earth and the sun and other heavenly bodies is usually referred to as *gravitation* (p. 423)

gregarious (grē gâr'ĭ u̯s). Living in groups. Gregarious animals are those that tend to flock together (p. 344)

Guericke, Otto von (gā'rĭk e̯ ŏt'ō fōn) (1602–1686). A German scientist who experimented with air pressure (p. 171)

gypsum (jĭp'su̯m). A mineral (a compound of calcium) which is used for improving soils and for making plaster of Paris (p. 7)

habitat (hăb'ĭ tăt). The place where a plant or animal naturally lives, as the seacoast or the desert. "Habitat groups" are exhibits made to show the plants and animals that are found in the same region (p. 391)

hardpan (härd'păn). Tough, clayey soil, through which it is difficult to dig (p. 274)

headwaters (hĕd'wô tẽrz). The source of a stream (p. 288)

heartwood (härt'wo͝od). The hard central part of the trunk of a tree (p. 310)

helium (hē'lĭ u̯m). A colorless gas which is very light in weight and does not burn (p. 177)

herbivorous (hẽr bĭv'ō ru̯s). Plant-eating (p. 348)

hibernate (hī'bẽr nāt). To spend the winter in a state of inactivity (p. 388)

hornblende (hôrn'blĕnd). A common dark mineral, a compound containing calcium, magnesium, aluminum, and other elements (p. 238)

humidity (hū mĭd'ĭ tĭ). The amount of water vapor in the air (p. 195)

humus (hū'mu̯s). Partly decayed vegetable or animal matter, used as fertilizer (p. 270)

hydrochloric (hī drō klō'rĭk) *acid.* A compound of hydrogen and chlorine dissolved in water (p. 253)

hydrogen (hī'drō je̯n). A colorless gas, the lightest element known. It is highly explosive when mixed with air (p. 177) *hydroid* (hī′droid). A name given to certain simple water animals, such as jellyfishes (p. 342)

igneous (ĭg′nē u̥s) *rocks.* Rocks formed when hot molten matter from deep within the earth cools and becomes solid (p. 236)

insect (ĭn′sĕkt). An animal with three separate body parts and six legs (p. 56)

iodine (ī′ō dīn). A shiny, brownish-black element (p. 101)

jellyfish. A boneless sea animal somewhat the shape of a cup turned upside down (p. 62)

larva (lär′vḁ) [plural *larvae* (lär′vē)]. The second stage in the life of insects, during which they eat large amounts of food. Larvae are often wormlike, and some are called caterpillars (p. 326)

larynx (lăr′ĭŋks). The part of the windpipe in which sounds are produced when the vocal cords vibrate (p. 393)

lava (lä′vḁ). Igneous rock which cooled down from the liquid state at the surface of the earth. The rock which pours forth from a volcano is molten lava (p. 241)

leach (lēch). To allow a liquid to seep through something (p. 274)

lichen (lī′ke̥n). A plant formation consisting of a fungus and an alga living together and needing each other to live. Lichens grow on the surfaces of rocks, trees, etc. (p. 265)

lime (līm). A compound of calcium and oxygen (p. 250)

limestone (līm′stōn). A sedimentary rock consisting of calcium, carbon, and oxygen. It is often formed from bits of sea shells (p. 252)

limewater (līm′wô tẽr). Water in which lime has been dissolved (p. 119)

linotype (līn′ō tīp). A machine which is used by printers to cast a line of type in one operation. Each letter need not be set separately (p. 40)

liquid (lĭk′wĭd). A substance that has a definite volume but has the same shape as the object which contains it (p. 54)

loadstone (lōd′stōn). An iron ore, called magnetite, which acts as a magnet (p. 443)

loam (lōm). A soil containing sand, clay, and humus (p. 275)

locomotion (lō kō mō′shu̥n). Movement from place to place (p. 373)

loess (lō′ĕs). Yellowish-brown loam which has been piled up by the wind (p. 279)

magnesium (măg nē′shĭ u̥m). A silver-white element. Its compounds are needed by plants (p. 283) *magnetism* (măg′nẹ̮ tĭz'm). The properties of a magnet. The most obvious property of a magnet is its ability to pick up pieces of iron (p. 443)

magnetite (măg′nẹ̮ tīt). An important iron ore, a compound of iron and oxygen, which sometimes has the properties of a magnet (p. 443)

manganese dioxide (măŋ′gạ̮ nēs dī ŏk′sīd). A black powder, a compound of oxygen with the metal manganese (p. 187)

marine (mạ̮ rēn′). Concerned with the sea. Marine plants and animals are those living in the ocean (p. 351)

mercury (mẽr′kū rĭ). One of the elements, a silvery metal, which is liquid at room temperature (p. 76)

metamorphic (mĕt ạ̮ môr′fĭk) *rocks*. Rocks that have been changed by heat and pressure. Both sedimentary and igneous rocks may become metamorphic rocks (p. 254)

meteor (mē′tē ẽr). A piece of material coming from space beyond the earth. When meteors strike the air, they are heated by the resistance it offers to their movement. We then see them as "shooting stars" (p. 163)

mica (mī′kạ̮). A mineral that may readily be separated into very thin, transparent sheets, which are more or less elastic. Mica is sometimes called *isinglass* (p. 238)

microscope (mī′krō skōp). An instrument which, by means of lenses, makes very small objects appear much larger (p. 60)

microscopic (mī krō skŏp′ĭk). Descriptive of an object that is so small that it can be seen only with the aid of a microscope (p. 61)

migrate (mī′grāt). To travel regularly from one region to another for feeding or breeding. Migration usually depends upon the season (p. 387)

mildew (mĭl′dū). A fungus or the white coloration produced by its growth (p. 208)

mineral (mĭn′ẽr ăl). A substance which has a definite chemical composition and is found in the earth's crust (p. 7)

mixture (mĭks′t͜ūr). A substance consisting of two or more other substances each of which keeps its own properties. The composition of a mixture may be different at different times (p. 80)

mold. A fungus or the woolly growth of the fungus (p. 208)

mongoose (mŏŋ′gōōs). A small animal of India which fearlessly attacks and kills the most poisonous snakes (p. 353)

mussel (mŭs′'l). A small water animal having two similar shells, each of which protects half of its body (p. 350) *natural* (năt͜ʹū răl) *gas.* A fuel gas obtained from the earth (p. 198)

natural resources (năt͜ʹū răl rē sōrsʹĕz). Material supplied by nature, such as mineral deposits, forests, and water power (p. 146)

nectar (nĕkʹtẽr). A sweet liquid produced by flowers, from which bees make honey (p. 304)

neon (nēʹŏn). A gas which is a very small part of the air. It is colorless, but it gives a red glow when an electric current is passed through it (p. 198)

nitrogen (nīʹtrō jẹn). A gaseous element which makes up about four fifths of the air and is present in all living things (p. 197)

nodule (nŏdʹūl). A knob formed on the roots of some plants, such as peas and clover, when certain very small bacteria leave the soil and enter the root. In the nodules bacteria reproduce very rapidly (p. 337)

obsidian (ọb sĭdʹĭ ăn). A pure natural glass, shiny and usually black. It is formed by the rapid cooling of lava (p. 243)

ocean basin. The deep hollow filled by the waters of an ocean (p. 241)

organ (ôrʹgăn). A part of a plant or an animal which has a particular use. For example, the heart is an animal organ; the flower is a plant organ (p. 317)

ovary (ōʹvạ rĭ). In plants the hollow portion of the pistil in which the seeds develop. In animals the organ in which the eggs are produced (p. 319)

oxygen (ôkʹsĭ jẹn). A colorless gas, the most abundant of all the elements. Oxygen is necessary for breathing. It makes up about one fifth of the air (p. 64)

palmist (pämʹĭst). One who claims to be able to tell fortunes, predict events, and judge character by study of the palm of the hand (p. 33)

parasite (părʹạ sīt). A plant or animal which obtains its food or shelter at the expense of another living thing (p. 342)

particle (pärʹtĭ kʼl). A very small amount of substance (p. 90)

passenger pigeon (păsʹẹn jẽr pĭjʹụn). A North American wild pigeon which once was very abundant. It nested in immense colonies, where it was shot and netted until it is now utterly destroyed (p. 146)

pellagra (pẹ lāʹgrạ). A disease due to lack of vitamin G in the diet (p. 414)

periwinkle (pĕrʹĭ wĭŋ kʼl). A small sea snail (p. 350) *phosphorus* (fŏs′fō ru̯s). An element which burns at a very low temperature (p. 186)

pickerel weed (pĭk′ẽr e̯l wēd). A kind of plant which grows in shallow water of streams and ponds (p. 66)

pilot fish. A fish which is often seen with a shark (p. 341)

pistil (pĭs′tĭl). An organ in the center of a flower; it receives the pollen and later contains the developing seeds (p. 318)

piston (pĭs′tu̯n). A sliding piece inside the cylinder of an engine or pump; it moves when it is pushed by gas or liquid (p. 16)

plaster of Paris (plȧs′tẽr ŏv păr′ĭs). A white, powdery calcium compound which, with water, forms a quickly setting paste (p. 186)

pollen (pŏl′e̯n). The fine yellow "dust" produced by flowers. It is necessary in the formation of seeds (p. 206)

pollution (po̯ lū′shu̯n). Making impure or unclean (p. 108)

Portland cement (pōrt′lănd sē mĕnt′). A cement made by burning and grinding a mixture of pure limestone and clay (p. 40)

potassium (pō tăs′ĭ u̯m). A soft, white metal which has many important compounds (p. 283)

potassium chlorate (pō tăs′ĭ u̯m klō′rāt). A white compound of potassium, chlorine, and oxygen (p. 187)

power (pou′ẽr). Rate of doing work (p. 120)

preservation (prĕz ẽr vā′shu̯n). The act or process of keeping from injury (p. 145)

primitive (prĭm′ĭ tĭv). Relating to the times of long ago (p. 29)

proportion (prō pōr′shu̯n). The relation of one part to another, or the relation of a part to the whole (p. 225)

protein (prō′tē ĭn). A complex substance which always contains nitrogen and which is a part of all living things. Some foods are especially rich in proteins (p. 338)

pumice (pŭm′ĭs). An igneous rock so full of tiny holes that it is very light (p. 243)

pupa (pū′pa̯) [plural *pupae* (pū′pē)]. The third stage in the life of some insects, during which they are very inactive. Cocoons contain and protect pupae (p. 326)

quartz (kwôrts). A hard, abundant mineral which is a form of silica. It may be colorless or colored; when pure, it is transparent (p. 238)

quartzite (kwôrts′īt). A metamorphic rock in which grains of quartz or sand are so firmly bound together that when the rock is broken it breaks through the grains as well as around them (p. 256) *radiant* (rā'dĭ ănt) *energy.* A form of energy which travels in straight lines, or rays, through empty space. When these rays strike a substance, the energy is absorbed and is changed to heat energy (p. 434)

ragweed (răg'wēd). A weed whose pollen is one cause of hay fever (p. 206)

reproduce (rē prō dūs'). To produce offspring, or young (p. 305)

reproduction (rē prō dŭk'shu̥n). The process by which plants and animals give rise to offspring (p. 307)

reservoir (rĕz'ẽr vwôr). A place where water is collected and kept for use when wanted (p. 98)

residual (rē zĭd'ū ăl) *soil.* A soil which is found where it was formed (p. 275)

rickets (rĭk'ĕts). A disease of the bones, caused by lack of vitamin D (p. 413)

root hairs. A fuzzy growth on rootlets. Water and dissolved minerals enter the plant through the root hairs (p. 309)

rootlet. A branch of one of the main roots of a plant (p. 309)

runoff (rŭn'ôf). The water which is removed from soil (p. 149)

sac (săk). A baglike part of animal or plant, often containing some special fluid (p. 326)

salamander (săl'a̤ măn dẽr). An animal which, like the frog, lives in the water as a tadpole and on land as an adult (p. 60)

sandstone. A sedimentary rock composed of sand grains cemented together (p. 249)

sapwood (săp'wo͝od). The living wood just beneath the bark. It is lighter in color and younger than the heartwood (p. 310)

scurvy (skẽr'vĭ). A disease caused by lack of vitamin C in the diet (p. 410)

sea anemone (a̤ nĕm'ō nē). A delicate sea animal. It gets its food and protects itself by means of hairlike cells which give it the appearance of a plant (p. 350)

sea urchin (ẽr'chĭn). A sea animal having a thin brittle shell covered with movable spines (p. 56)

sedge (sĕj). A grasslike plant which often grows in bunches in swampy places (p. 66)

sediment (sĕd'ĭ me̥nt). Solid particles which settle out of water (p. 247)

sedimentary (sĕd ĭ mĕn'ta̤ rĭ) *rocks.* Rocks formed by the cementing together of sediments (p. 245)

sepal (sē'păl). A leaflike structure, one of several which make up the outer circle of parts of a flower (p. 318) *shale* (shāl). A sedimentary rock formed from fine bits of mud or clay (p. 252)

silica (sĭl′ĭ ka̤). A compound containing oxygen and the element silicon. The sand of the seashore is a variety of silica (p. 250)

siphon (sī′fŏn). A tube for moving liquids from one place to another. In clams and similar water animals, there are two tubes called siphons. Water carrying food and oxygen enters the animal's stomach through one siphon, and water carrying waste leaves through the other (p. 370)

social (sō′shăl) *insects*. Insects that live together in more or less organized communities (p. 346)

social living. Living together as a group, the members of which are, to some extent, dependent on one another (p. 345)

sodium. A soft, silver-white metal whose compounds are very abundant. Salt, washing soda, and baking soda are compounds of sodium (p. 406)

solid (sŏl′ĭd). A substance which has a definite volume and shape (p. 75)

soluble (sŏl′ū b'l). Able to dissolve. Sugar is soluble in water (p. 103)

solution (sō lū′shṳn). A substance dissolved in another, usually a liquid (p. 103)

soothsayer (so͞oth′sā ẽr). One who claims to be able to foretell events (p. 30)

Spallanzani, *Lazaro* (späl län dzä′nē lät′sä rō) (1729–1799). An Italian scientist who is especially noted for his work on digestion and respiration. He proved that living things could not be produced from nonliving matter (p. 18)

spinal meningitis (spī′năl mĕn ĭn jī′tĭs). A disease of the brain and spinal cord caused by bacteria (p. 210)

sponge (spŭnj). A sea animal which grows in a plantlike fashion. Its skeleton can absorb large amounts of water when wet without losing its toughness (p. 62)

spore (spōr). A single cell produced by some plants. Although it is not formed by the union of two cells, as a seed is, it is able to develop into a new plant. Ferns and mushrooms are examples of plants which produce spores (p. 208)

stalactite (sta̤ lăk′tīt). Limestone hanging like an icicle from the roof or sides of a cavern (p. 263)

stalagmite (sta̤ lăg′mīt). A spike of rock (like a stalactite turned upside down) formed on the floor of a limestone cave by drippings from the roof (p. 263) *stamen* (stā′mẹn). An organ near the center of the flower; it produces the pollen (p. 318)

starfish (stär′fĭsh). A small sea animal whose rough body is shaped like a star (p. 56)

subsoil (sŭb′soil). The loose, broken material which lies under the surface soil (p. 276)

sulfur (sŭl′fẽr). A yellow element. One of its uses is in making matches. Sulfur is a part of protein foods (p. 201)

tapeworm (tāp′wẽrm). A worm which lives in the intestines of men and various animals (p. 343)

television (tĕl′ē vĭzh u̮n). The process in which electrical waves are used to send a picture from one place to another (p. 40)

termite (tẽr′mīt). A pale-colored social insect with a soft body (p. 335)

terrarium (tĕ râr′ĭ u̮m). An enclosure in which land plants and animals may live and be studied (p. 329)

test tube. A plain, thin glass tube closed at one end, used for making sample tests of different substances (p. 78)

thorax (thō′răks). In insects the middle of the three sections of the body (p. 322)

topsoil (tŏp′soil). The surface soil as distinguished from the subsoil (p. 276)

Trichina (trĭ kī′na̮). A small worm which lives in the muscles of man and other animals (p. 343)

tungsten (tŭng′stẹn). A steel-gray metal with a very high melting point. It is used to make the filament in electric-light bulbs and to toughen steel (p. 447)

turbine (tẽr′bĭn). A machine in which running water or steam is used to produce electricity (p. 40)

typhoid (tī′foid) *fever.* A disease caused by bacteria taken into the body in food or drinking water (p. 108)

universe (ū′nĭ vẽrs). An enormous group of stars. What we call our sun is a star in one such group (p. 26)

vacuum (văk′ū u̮m). A space which contains no matter (p. 162)

Vallisneria (văl ĭs nē′rĭ a̮). A plant which grows under water in ponds and streams. It has very long narrow leaves and is called eelgrass (p. 58)

valve (vălv). An opening in a tube or container which allows gases or liquids to pass (p. 166) *vegetarian* (vĕj ē târ′ĭ ăn). Plant-eater (p. 323)

ventilation (vĕn tĭ lā′shu̯n). The process of keeping the air in a room in a comfortable, healthful condition (p. 219)

vibrate (vī′brāt). To move back and forth (p. 393)

vitamin (vī′ta̯ mĭn). A compound which we must take into our bodies if we wish to remain healthy (p. 409)

volt (vōlt). A measure of the pressure which forces electricity through a substance (p. 445)

Volta (vôl′tä), *Alessandro* (1745–1827). An Italian scientist who studied electricity and made the first electric cell (p. 445)

walking stick. An insect which eats leaves and looks very much like the twigs and branches on which it is found (p. 327)

water cycle. The continuous process in which water is evaporated into the air and falls again as rain (p. 86)

water table. The top of the ground water. This may be at the surface of the earth or below the surface (p. 148)

water vapor. Water in the form of a gas. Usually the phrase means water vapor at a temperature less than the boiling point, but sometimes it is used to mean steam (p. 85)

watershed. The whole region from which water drains into a river or lake (p. 110)

weight. The amount of pull exerted upon an object by the force of gravity (p. 67)

whirligig (hwẽr′lĭ gĭg) *beetle.* A beetle which lives mostly on the surface of water. It moves rapidly about in curves (p. 371)

work (wẽrk). Work is done whenever an object is moved (p. 120)

yeast (yēst). A tiny plant. It changes sugar solution into alcohol and carbon dioxide (p. 208)

zinc. A bluish-white element; a metal (p. 445)

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